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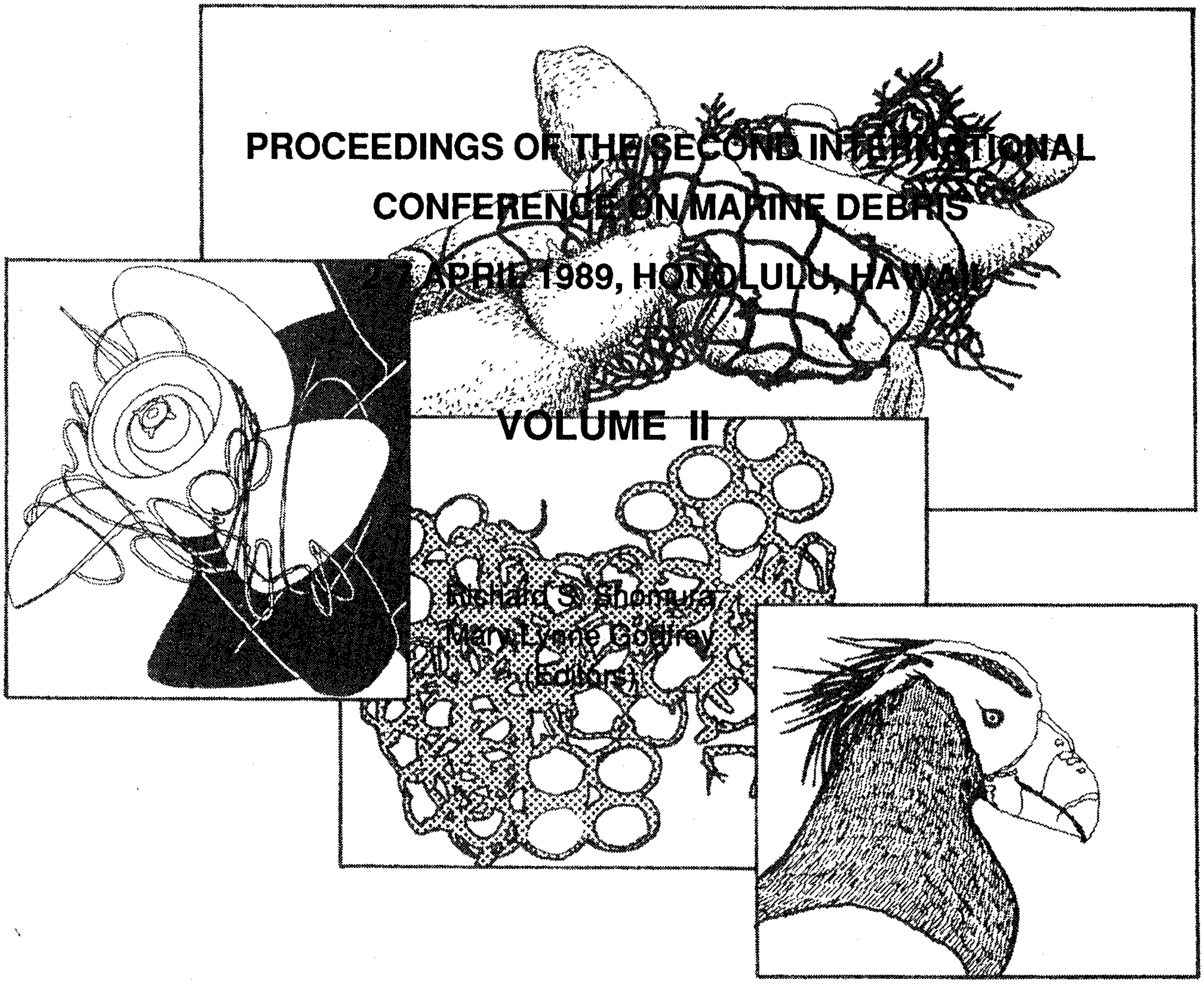

PROCEEDINGS OF THE SECOND INTERNATIONAL CONFERENCE ON MARINE DEBRIS

2-7 APRIL 1989, HONOLULU, HAWAII

VOLUME II

Richard S. Shomura
Mary Lynne Godfrey
(Editors)

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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AN ECONOMIC PERSPECTIVE ON THE PROBLEM OF MARINE DEBRIS

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ABSTRACT

This paper examines the role of economic analysis in the development and implementation of an effective public policy to address the problem of marine debris. The economic theory of common property resources and other relevant aspects of natural resource and environmental economics are explained and used as a basis to critically review the economics literature on marine debris. Gaps in knowledge are identified and an economic data collection and research agenda is proposed.

INTRODUCTION

Many of the economic issues associated with the problem of marine debris are similar to those surrounding oil and hazardous substances pollution of the marine environment. The marine debris problem has not, however, received the same degree of attention by the research community as oil and hazardous substances pollution has. This is particularly true in the field of natural resource and environmental economics, as the review of the literature amply illustrates. Although a number of studies have shown that marine debris can have deleterious effects on marine life (Balazs 1985; Calkins 1985; Day et al. 1985; Bengston et al. 1988; Cooper et al. 1988), the current body of knowledge is insufficient to provide an assessment of the magnitude of the problem. And although research is continuing on the impacts of marine debris, neither does a coordinated effort exist to structure this research toward providing such an assessment, nor are efforts under way to ensure that research results are formulated in a way that will be useful for economic assessments.

This paper provides an overview of the economic aspects of the marine debris problem and suggests how economic analysis can play a role in finding effective and rational solutions. A research agenda is proposed to aid in quantifying the economic dimensions of the problem and assessing the effectiveness of economic incentives in achieving compliance with various laws and regulations.

In R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

THE ECONOMIC PERSPECTIVE

Absent significant economic incentives, compliance with environmental laws and regulations is usually low. It is true that education, moral suasion, and fear of punishment will stimulate many to abide by laws and regulation, but past experience has shown that these efforts alone will not significantly reduce noncompliance with environmental regulations. Here we discuss how an economist would approach analytically the problem of marine debris, including the issue of compliance with prohibitions on debris disposal.

Background

In order to show how economics can be used in analyzing the problem caused by marine debris, it is necessary to provide a brief description of the economic theory of natural resource and environmental economics. This will help clarify some of the concepts behind such familiar terms as market failure, economic efficiency, benefit-cost analysis, economic damage assessment, the value of environmental improvement, and cost effectiveness. These terms are related to methods for analyzing policy alternatives designed to correct problems in the way individuals use scarce natural resources (including environmental goods and services).

The literature on the problem of marine debris highlights a wide range of detrimental impacts on living and nonliving resources. These detrimental impacts are known, generally, in economic terms as external diseconomies (or simply "externalities" for ease of exposition). Externalities arise when the marketplace fails to balance competing uses of a resource so that a particular resource's value to society is maximized. Under ideal circumstances, competitive markets will consider all the costs and benefits of an activity, balance competing uses, and produce the maximum net benefit to society. Thorough study of the market failures which result in marine debris would undoubtedly lead to more effective solutions.

Common Property Resources and Nonmarket Goods

Two sources of market failure predominate in the natural resource and environmental economics literature: common property resources and nonmarket goods. One type is discussed in a classic article by Hardin (1968) who wrote of the "tragedy of the commons." Common property is overexploited because everyone has the right to use it, but no one has personal responsibility for it. Rivers, estuaries, and oceans are examples of common property. It is not surprising then that these bodies of water are overutilized as waste repositories, since dumpers do not have to pay the full social cost for their use. Given the rising, high cost of land-based disposal, we can expect pressure on these resources to continue.

Even if private property rights for natural resources exist, the second type of market failure occurs because markets cannot be easily organized for many environmental goods and services. They form a general category called "nonmarket goods and services." An example of the existence of market failure where private property rights exist is in the market for wetlands. Many wetlands are privately owned but may be used in a nonoptimal way by the private owner because he or she cannot capture the many social (public) benefits produced, such as water recharge, storm protection, water purification, wildlife habitat, and fishery production. The wetland owner is unable to identify the beneficiaries or measure the amount of individual benefit for each of these services, therefore these services go unpriced and undervalued in actual market transactions. From the owner's point of view, he or she may maximize the value of wetlands by developing them, but from society's point of view wetlands may be misallocated since the value of nonmarket services is ignored.

The marine debris problem combines both types of market failure. Most of the resources affected, living and nonliving, are common property and have nonmarket values. Effective solutions to the marine debris problem must focus on resolving these two market failures. Implementing systems of private property rights in the rivers, estuaries, and oceans does not seem feasible. The solution to the common property resource problem has largely been government ownership and management. The government, it is often assumed, could represent and balance competing uses of resources if all the costs and benefits of the various activities were known. The government, acting as the private sole owner, could presumably maximize the value of its resources. However, experience has shown that such an outcome is not likely for a variety of reasons: lack of information, overlapping jurisdictions, conflicts of interests across jurisdictions, and the co-opting of politicians and managers by a particular interest group, to name a few.

Markets are vitally important sources of information on the value of goods and services. It is this aspect more than any other that leads to efficient outcomes from smoothly functioning markets. The costs and benefits of various courses of action are discovered through billions of private transactions. The major problem for nonmarket goods and services is the absence of quantifiable information about the costs and benefits of actions which affect them. Two broadly defined categories of nonmarket goods and services are expected to account for a major portion of the social costs of marine debris: recreational use value and intrinsic value of natural resources and the environment.

Recreational Use Value

Recreational use is generally recognized as second in importance only to human health as a beneficiary of water pollution control. Over the past 20 years, economists have been developing information collection and analytical techniques to estimate the recreational use value of natural resources. Survey sampling techniques and the use of questionnaires are the primary methods of information collection. Analytical techniques fall into two general categories; demand modeling and the use of direct valuation questions, e.g., contingent valuation approach. In demand modeling, individual expenditures on goods and services used in producing a recreational experience serve as proxies for actual market prices. In the contingent valuation approach, individuals are given a hypothetical situation defining the quantity and quality of the recreation experience. They are then asked how they would value in dollar terms a particular change in the quantity or quality of a recreation resource. Some economists prefer the demand modeling approach because it is based on actual behavior; others prefer the contingent valuation method because of the flexibility it provides for addressing incremental environmental changes. Both have imperfections, and research on improved methods for estimating recreational use values continues.

Intrinsic Value

One of the value categories that is often excluded from estimates of the total economic value of nonmarket goods is referred to as intrinsic value. This term is used to define values that people place on natural resources that are independent of their present use. These values can be reduced by human activities that lower the quantity and quality of the resources in question. Such values appear to derive from a variety of motives including the desire to bequeath a legacy of natural resources such as clean oceans to future generations, or the sense of well-being that results from simply knowing that certain natural resources exist.

In the few empirical studies that have been completed to date, aggregate intrinsic values for unique natural resources have been shown to be quite large. As to the likely ratio of intrinsic values to use values, it is still too early to draw any firm conclusions. Most who have studied this issue agree that intrinsic values exist, but continue to debate how they can be measured accurately. The methods of collecting and analyzing data on intrinsic values closely follow the contingent valuation method used for recreational use values. Research on this important area of valuation is likely to intensify in the near future.

Efficient and Equitable Allocation of a Pollutant

Economic efficiency is one normative criterion for judging various policy outcomes. It is based on the maximization of the net social benefits to society from any activity (net benefits being equal to total social benefits minus total social costs). It is a normative criterion because there are an infinite number of economically efficient outcomes, each associated with a different distribution of wealth and income. A change in the distribution of wealth and income could change the benefits and costs of any activity and therefore the amount of the activity that is economically efficient. The distribution of wealth and income is another normative criterion used for judging policy outcomes and is commonly referred to as the equity or fairness criterion. Economists artificially separate the two criteria of economic efficiency and equity in order to make analysis tractable. Below, the concepts of economic costs and benefits and the economically efficient allocation of a pollutant are discussed. Following that, equity and another criterion related to efficiency, cost effectiveness, are presented.

Economic Costs

The fundamental economic measure of the cost of any action is its opportunity cost. This basic concept has an analogy in physics: two objects cannot occupy the same space at the same time. In other words, one cannot undertake one activity without giving up something else. Opportunity cost, therefore, measures the value of the next best thing forgone in order to have the preferred choice. Social cost is simply measured by how much of some other thing is given up in order to have the preferred choice. For example, to estimate the full social cost of cleaning a marsh after an oil spill, one should count the opportunity costs of all the equipment, supplies, and wages paid to employees (using market prices), plus the nonmarket opportunity costs of any physical damage done (including those caused by the cleanup itself). Of course measuring the value of the aesthetic and biomass damage inflicted, since there is no market price established for them, is difficult.

Opportunity costs are incurred regardless of whether monetary transactions, or exchanges, take place. Both explicit costs, which show up in an accounts ledger, and implicit costs should be included in any full social cost accounting of a change in the quality or quantity of a natural resource. For example, the social cost of a beach littered with debris includes the cost of cleanup plus the lost enjoyment of the beach caused by the nonmarket aesthetic insult of the debris' presence until the cleanup is accomplished. Thus the social costs of any activity (beach litter) include the lost benefits from other activities impaired by that activity (beach use).

Economic Benefits

A benefit is the economic value of any good or service that provides utility or satisfaction to one or more individuals. Benefits enhance a person or group's well-being. They can be derived from the consumption of commodities such as offshore oil and gas, or fish, or from nonconsumptive enjoyment of a sunset or body surfing. Commodities, especially those valued in the competitive marketplace, where externalities do not exist, are much easier to measure because their prices are determined in arm's length exchanges which reflect the consumer's willingness to pay and the cost of all inputs used in their production.

Economic Efficiency

Economically efficient outcomes in the choice between competing activities are ones where net benefits (total benefits minus total costs) to society are maximized. When dealing with pollution, this concept is more easily understood by an equivalent formulation involving the minimization of two rather different types of costs: damage costs and control (or avoidance) costs. In the case of marine debris, damage costs would include such social costs as lost recreational use, intrinsic damage such as harm to pristine environments or marine mammals, and damages to ships from entanglement of propellers and steering gear. Control or avoidance costs include the cost of avoiding the pollution as well as the cost of removing or recycling the marine debris causing the harm.

The economically efficient outcome will occur at the quantity of marine debris corresponding to the point where the marginal control cost is equal to the marginal damage cost. This is shown in Figure 1 as point Q*.

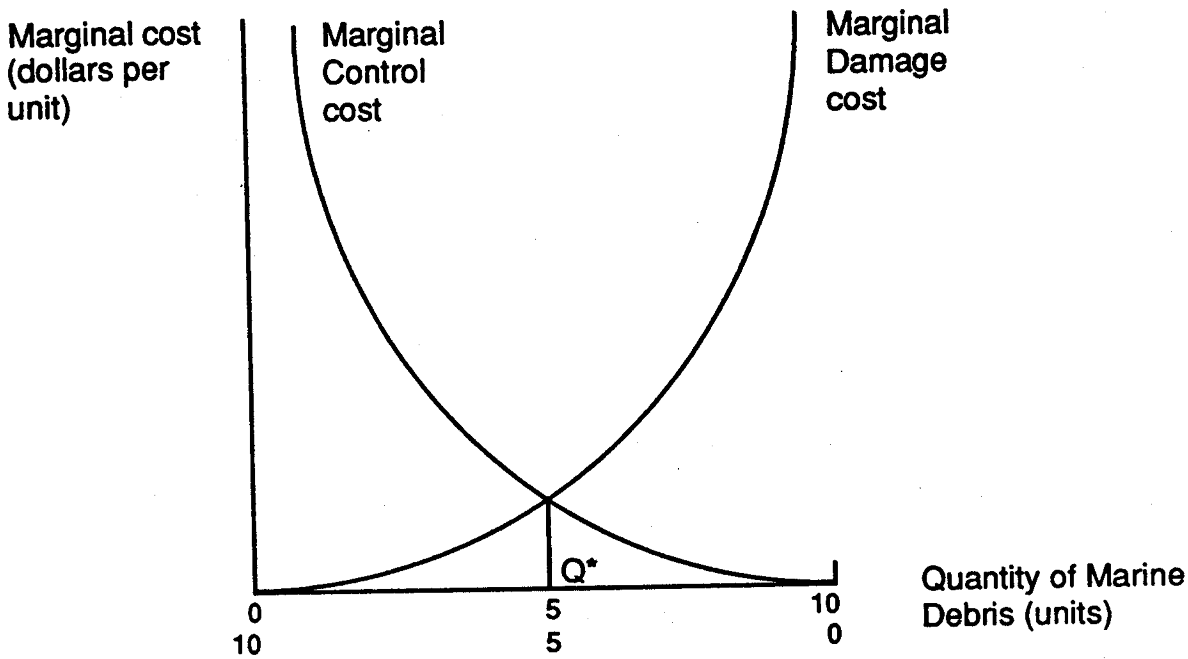

Figure 1.--Efficient allocation of a pollutant--static case.

A nonzero optimum quantity of marine debris at point Q* implies that there is some benefit from the use of products that end up as marine debris. Reducing the quantity of marine debris below Q* would be inefficient from society's point of view because the social cost of reducing it by an additional unit would exceed the value of an additional unit of other goods and services otherwise damaged. The zero level of marine debris is not a socially desirable outcome in this case.

The above static analysis assumes that marine debris items are not persistent pollutants, that is, the pollutant does not have detrimental impacts over many time periods. Some forms of marine debris, however, are persistent pollutants. Even if all marine debris were controlled today, the amount accumulated in the environment would still have detrimental impacts for years to come. Because of the persistent nature of this type of pollutant, the analysis of the efficient pollutant level must take into account the intergenerational transfer of costs and benefits. In economics, we call this the dynamic efficiency criterion. Dynamic efficiency would be achieved at the pollutant level that maximizes the present value of net benefits over time. The mathematical formulation would be:

$$PV[B_1 \ldots B_n] = \sum_{i=0}^{n} \frac{(B-C)_i}{(1+r)^i}$$

where B equals the total benefits of the goods that are produced jointly with the pollutant, i.e., marine debris; C the total cost of producing these goods plus the cost imposed on other goods and services impacted by the marine debris; i the time period; and r the social discount rate used to make net benefits comparable across different time periods. The dynamically efficient allocation of a pollutant in this case has to satisfy the condition that the present value of the marginal net benefit from the last unit in period one equals the present value of the marginal benefit in each following period (Tietenberg 1988).

There is one interesting difference between the first efficiency outcome presented in Figure 1 (the static efficiency criteria) and the dynamically efficient outcome. In the dynamically efficient outcome, new marine debris after a certain amount of time must be eliminated. In the static outcome of Figure 1, Q*, marine debris enters the environment each new time period. However, the dynamically efficient outcome recognizes that marine debris such as plastics causes damage over many periods. Thus, as marine debris continues to accumulate in the environment, not only the new but also the old marine debris is causing damage resulting in social costs. At some future time the old marine debris will have accumulated to a point where the costs are so high that economic efficiency requires the elimination of all new marine debris. That is, the point is reached where it is less costly to recycle all new marine debris or switch to cheaper substitutes.

Equity

As mentioned above, there are an infinite number of economically efficient allocations of marine debris depending upon the distribution of wealth and income. Wealth, broadly speaking, would include the amounts of both human and nonhuman capital a person owns. Human capital is a person's skills and abilities. Income is a flow from the stock of human and nonhuman capital. An increase in marine debris may result in an increase in the cost of beach visitation, since a person may have to travel further to get to a clean beach. This increase in cost can be thought of as a decrease in income available to the person to purchase other goods and services--an opportunity cost. Equity addresses the question of fairness in the distribution of net benefits from any activity. No generally accepted standards of fairness exist. Resolution of disputes over fairness are generally resolved in political or judicial processes. Implementation of policies that have high net benefits can fail because the benefits of the activity are concentrated in one region of the country and the costs in another. Unless the region that is disadvantaged is compensated for the added costs imposed by the policy, the policy may be defeated. There are several criteria that are generally used in evaluating the issue of equity. They are horizontal equity, vertical equity, and sustainability.

Horizontal equity occurs when people with equal incomes are treated equally. This can be used in judging the geographic fairness of a given policy. If people with comparable income levels in different parts of the country receive different net benefits, the horizontal equity criterion is violated.

Vertical equity deals with the treatment of unequals or those with different incomes. In assessing vertical equity, net benefits are distributed among income groups either progressively, regressively, or proportionally. Distribution is said to be proportional if the net benefit received is proportional to income. It is said to be regressive if the net benefit represents a larger proportion of the income of the rich than of the poor, and is progressive if, as a proportion of their income, the poor receive a larger share than the rich. Since many of our societal programs are designed to aid the poor, it is usually assumed that regressive policies are bad. Some economic efficiency may be sacrificed to achieve greater equity.

The last criterion is sustainability. This involves intergenerational transfers of net benefits. As we have seen in the discussion of efficiency above, the marine debris problem can be characterized by intergenerational transfers because of the persistent nature of the pollutant. The sustainability criterion suggests that, at a minimum, future generations should be left no worse off than present generations.

Cost Effectiveness

A concept more closely related to the efficiency criterion of policy is the cost effectiveness approach. Under this approach it is recognized that, due to the lack of full and accurate information, determination of the optimal efficiency point is impossible. The cost effectiveness approach evaluates policies and management strategies as to the least costly way in which a given level of environmental quality can be achieved. In the case of persistent marine debris, the economically efficient solution may be an eventual ban on its use and disposal in the oceans altogether. However, compliance with such a ban would likely result in economic hardship for certain sectors of the economy and would be costly to enforce.

Laws and regulations that contain market-based incentive systems are, in theory, less costly than traditional regulatory approaches. Incentive systems use market forces to reduce pollution by requiring polluters to pay all or part of the social cost of their activity. They are penalized economically for high levels of pollution and are rewarded with lower fees for reduced levels of pollution. The laws and regulations that currently exist on marine debris do not contain market-based incentive systems to achieve compliance. This is an area where future research could pay big dividends.

Economic Impact

Many government officials appear more persuaded by the effects of their decisions and policies on sales, employment, and income, i.e., economic impact, than by efficiency, equity, sustainability, or cost effectiveness. Much of the time, concern about sales, employment, and income is expressed in terms of equity or fairness and reflects genuine concern for the health and welfare of people in the communities affected by various decisions and policies. However, economists would generally agree that maximization of sales, employment, and income are not preferable to economic efficiency as objectives of social policy, since irrational conclusions are often derived from analyses based upon maximization of economic impact. An example should help clarify this point.

Consider Figure 2, showing the demand and supply of commercially caught fish. The demand for commercially caught fish is shown in D_1; S_1 and S_2 are the supply of fish before and after pollution, respectively. Before pollution, consumers purchase Q_1 pounds of fish per time period at price P_1 per pound. Total sales revenue is equal to the area OP_1AQ_1.

If pollution reduces the stock of fish, the supply curve shifts back to S_2 and consumers now purchase only Q_2 pounds per time period at the higher price, P_2. Total revenue is now equal to the area OP_2BQ_2. The problem with this analysis is that total revenue may have increased, decreased, or remained the same depending upon the price elasticity of demand. If demand is inelastic (a 10% increase in price will result in a <10% decrease in quantity demanded), then total revenue will increase. Thus, when demand is inelastic, if pollution reduces fish stocks it results in increases in total sales revenue.

Now consider the efficiency approach. Area $P_1P_1{*}A$ measures the net value (consumer's surplus) associated with commercial fishing before the pollution. This would be a measure of the net benefits of commercial fishing to society. Now when pollution reduces the stocks, supply shifts to S_2 and the new consumer's surplus is equal to the area $P_2P_1{*}B$, which is less than the area $P_1P_1{*}A$ by the amount equal to the area P_1P_2BA. Thus, using the efficiency criterion, there is a net loss to society from the pollution injury to this commercial fishery. This loss would then be compared to the gains in consumer's surplus from the products that result in the pollution to determine if society gains or loses from their production.

Such comparisons are commonly known as benefit-cost analyses. They provide more comprehensive information to decisionmakers about the overall result of a given project or policy change than the rather incomplete picture conveyed by economic impact analyses. A benefit-cost analysis can help determine whether, for example, the social benefits of a specific set of policies to reduce marine debris outweigh their costs.

Categories of Social Cost

The following categories can be delineated as the major areas of known economic costs or externalities associated with marine debris:

- Commercial fisheries. Through what is called "ghost fishing," discarded or lost nets and other types of debris can entangle fish and reduce the quantity of various species and thereby impose costs on fishermen and consumers. Debris can also become entangled in fishermen's nets and either damage them or cause them to operate inefficiently.

- Ships. Debris can become entangled in the propellers and steering gear and can clog the water intake of vessels, thereby causing physical damage to ships of all types, including recreational fishing, cargo, military, and research vessels, and imposing repair and delay costs on their owners.

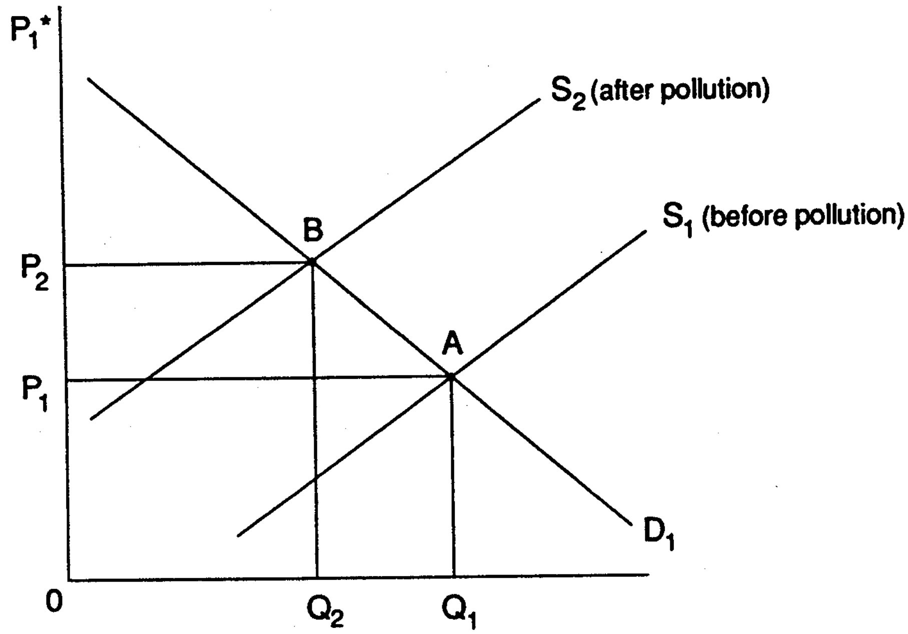

Figure 2.--Impact of pollution on the supply of commercially caught fish.

- Marine mammals, birds, and turtles. Through entanglement in and ingestion of plastics, we know that large numbers of birds and animals become injured and die, imposing costs on those members of society who obtain use value from these animals through viewing, hunting, and scientific research, or intrinsic values from the mere fact that these organisms exist.

- Recreation, such as beach use, hiking, camping, and picnicking. Debris causes aesthetic losses, as demonstrated by users who are willing to go to considerable expense to avoid it, such as through cleanup of beaches or extra travel to recreate in areas with less debris. Property owners in coastal areas may also suffer reductions in the value of their property if debris renders it less desirable from an aesthetic or recreational standpoint.

- Long-term impact. There could be other, as yet unknown, long-term impacts of marine debris on the health of humans and the biota which now, or may at some time in the future, impose unexpected costs on society.

The State of Economic Knowledge on Marine Debris

To date there have been only a handful of economic studies directed at the problem of marine debris. The present state of knowledge is reminiscent of what was known about the economics of oil spills and their prevention some 20 years ago. A small number of studies have been conducted by state or local governments on the out-of-pocket costs but not necessarily the full opportunity costs of cleaning up small sections of beaches. There has been one detailed study on the effects of debris on individuals' willingness to pay for tourist accommodations in a small area of coastal Massachusetts several years ago (Wilman 1984). It revealed that overnight tourists did place a premium on reduced quantities of beach debris. However, the study ironically did not set out to measure the benefits of debris reduction, but rather the economic costs of oil spills on Cape Cod beaches. Since there were no actual oil spills there to study, the author used debris as a surrogate for the effect of oil on the value of beach recreation. There has also been one study on the costs of recycling shipboard plastic waste in the Port of Newport, Oregon (Recht 1988). It provides some useful information and anecdotes of what such a program entails from both a management and a cost standpoint. And finally, there has been one paper written on the types of economic incentives that might be applied to the problem of debris and what general types would likely be effective (Sutinen 1988). At present there are economic studies under way on some aspects of the debris problem that plagued the New England and mid-Atlantic coasts of the United States during the summers of 1987 and 1988.

In addition to the modest amount of economic research directed at the debris problem, there is some important complementary research being conducted on the value of various types of beach use, intrinsic values of natural resources, the costs and benefits of waste recycling programs, and the costs and marketability of degradable plastics. Results of such governmental and academic research programs can be found in the natural resource and environmental economics literature.

RESEARCH AGENDA

A review of the literature reveals that there is little known about the magnitude of the marine debris problem or of its social costs (or conversely, the benefits of a reduction in the quantity of debris). Justification of public programs to mitigate or eliminate these costs will require such estimates. But knowledge of these costs is only a first step. Laws and regulations require changing people's behavior to bring them into compliance. Market-based incentives will likely be the most cost-effective means of achieving compliance. Research is therefore needed on the relative effectiveness of various market based incentive programs in achieving compliance with various laws and regulations. Below is a list of suggested research projects that partially address both the issue of identifying the magnitude of the social costs of marine debris and various market-based incentive programs.

Social Costs

Aesthetics

Debris makes beaches and other recreational areas less attractive. Shorefront properties are also made less attractive, but whereas the loss in value of shorefront properties may show up in market transactions, the recreational values are nonmarket. Two studies are recommended to help understand the magnitude of this type of economic loss.

1. A study of the economic costs of debris on a specific set of beaches. This study would pick a set of beaches and investigate the economic value of lost services that would result from different levels of debris on the beach. The beaches chosen would ideally have wide regional representation. The study should be designed so that the methodology and the loss estimates could be expanded to other regions of the country.

2. A study of property value losses due to marine debris. Property value studies have been used by economists in estimating the economic damages from various environmental pollution problems. These techniques could easily be extended to the marine debris problem. Several regional studies should be conducted to show the effects throughout the nation.

Intrinsic Value

Debris traps and entangles fish and wildlife. Fish and wildlife also ingest various types of debris resulting in morbidity and mortality. This type of physical injury to the environment results in economic damage to individuals that value the right of fish and wildlife to exist or remain unharmed in pristine environments.

A study could be made of the economic cost incurred when individuals of some subpopulation of a noncommercial species (e.g., birds, mammals) become entangled in or ingest marine debris. This study could involve the threat of extinction or only the loss in social value when a small number of a species are lost or harmed. The study should be based on a national survey since many individuals outside coastal areas will experience this type of loss.

Fouling of Vessels and Fishing Gear

When vessels and their gear are impaired by contact with marine debris, there are two kinds of costs: a) the repair and replacement cost for the damaged gear and b) the opportunity cost of the vessel and gear when it is not in productive service. Commercial fishing or shipping impacts entail market losses, but for recreational boating, market and nonmarket losses must be considered. Two projects could be undertaken to quantify the incidence of impairment and the magnitude of costs.

1. Investigate the incidence of impairment for each of the following industry groups: commercial fishing, shipping, and recreational boating. Research should attempt to quantify the extent of the problem nationally and identify regions of critical concern.

2. Estimate the magnitude of costs for each of the three industry groups above. These could be small surveys among owners or operators in each of the industry groups. Areas

identified as representing the most severe problems should be used for each industry group.

Commercial and Recreational Fisheries

The greatest impact of marine debris on fish stocks is, apparently, the ghost fishing phenomenon. A secondary, but potentially large, impact is the possibility that consumer perception of contamination of fish stocks by marine debris can influence the demand and price of related fish products. This impact could extend to recreational fisheries because one of the main components of value in the recreational fishery is the consumption of fish.

1. Ghost fishing. Ghost fishing has an economic cost in terms of the wasted resource. For commercial fisheries it is the market value of the lost product, whereas for recreational fisheries it is the lost value due to lower catch rates. This project should involve both biologists and economists. Current economic research on the impact of catch rates on recreational fishing demand and value could be utilized in assessing the cost of ghost fishing.

2. The impact of perceived contamination on the price of and demand for fish. A project which collects and describes incidents of market effects (i.e., commercial fisheries only) from perceived contamination would provide at least some evidence of the economic costs of marine debris. A survey of the economics literature and of knowledgeable people to gather these incidents in the form of a research report should be conducted. Additional studies could follow, if warranted.

Compliance and Incentives

The greatest challenge in resolving the marine debris problem will be in finding and implementing the right mix of market-based incentives and enforcement to bring about compliance with various laws and regulations on the disposal of debris. The following projects would investigate the use of fees and incentives as part of the marine debris solution.

1. Deposits on the return of nondegradable products. The efficiency of deposits on beverage containers as a means of controlling land debris is well documented. This research project would investigate the potential for deposits for the return of plastic marine debris. It should focus on coastal states which have experience with deposit systems.

2. Fees on the use of nondegradable materials. Business firms and households are good at allocating scarce resources which they must pay for. Fees on plastic would be an incentive to substitute other materials. However, business firms must be treated differently from the household sector because

foreign firms could simply displace domestic firms. Foreign made products using a host of nondegradable but cheaper materials could replace domestically produced goods made of more expensive degradable materials. This project would investigate the feasibility of fees on potential debris in the marine environment.

3. Investigation of the economic gains that can accrue to a particular region as a consequence of consolidating waste handling facilities. New U.S. laws require that vessels bring their nondegradable waste to port. Ports are required to handle the solid waste. Within particular regions, it may be very costly for ports to handle all of the vessel-borne waste. An economic study of the costs of onshore waste handling would prepare ports for the resource demands and for setting port fees. When the costs differ among ports, there may be incentives to use different ports. Further, there are incentives to dump trash if fees are based on the amount of trash that is brought ashore.

4. Investigation of alternatives to traditional methods of compliance. Policies combining punishment and reward which partly subsidize the adoption of compliance techniques and impose clear penalties for the absence of compliance are used elsewhere in government regulation. This research program, would study compliance programs which include education, incentives, and penalties for a specific portion of the industry.

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ESTIMATION OF DAMAGES TO FISHING VESSELS CAUSED BY MARINE DEBRIS, BASED ON INSURANCE STATISTICS

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ABSTRACT

An estimation has been made of the number of accidents, the amount of damage, and losses to and of fishing vessels caused by marine debris, based on data available from the insurance covering fishing vessels. Such accidents, damage, and losses caused by debris in the sea include those resulting from collision with drifting objects, entanglement of floating objects in the propeller blades, and clogging of the water intake for the engine cooling system. According to insurance statistics, losses attributed to the above-mentioned causes were ¥4.4 billion in 1985, whereas the losses and damage sustained by all the fishing vessels of <1,000 gross tons in Japan are estimated at ¥6.6 billion per year.

INTRODUCTION

Since ancient times, many different kinds of objects drifting in the sea have endangered ships. In the past, drifting wood and blocks of ice usually made up such driftage. More recently new kinds of debris including discarded plastic materials have emerged. Accidents and trouble caused by lost or discarded fishing nets and ropes becoming entangled in propeller blades, and the overheating of engines resulting from plastic debris clogging the water intake of an engine cooling system have been reported.

However, there are very limited statistical data available showing the number of vessels damaged by marine debris and the magnitude of the damage and losses. The reason for this lies in the fact that there are few systems for collecting such statistical data. On the other hand, at least part of such damage is covered by insurance, and by analyzing insurance-related data, it is possible to obtain approximate figures on the number of cases and the amount of damage.

In Japan, there is an insurance system for fishing vessels of 1,000 gross tons (GT) based on the Compensation Law Concerning Damages, etc., to Fishing Vessels. Established for the purpose of stabilizing the fishing industry which, is said to be subject to a great many dangers, this system

In R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

operates with a subsidy from the central government. As many as 60% of all fishing vessels of <1,000 GT are covered by this insurance system.

This insurance covers a wide range of damage to fishing vessels including damage such as sinking and fire, damage to the cargo including fish caught and stored on board, and loss of life of the crew. Also covered by the insurance are accidents resulting from marine debris.

This report illustrates the accidents and trouble sustained by fishing vessels in Japan as documented by a nationwide organization handling damage insurance (the Fishing Vessel Insurance Center, which is principally in charge of management of the insurance system) and estimates the magnitude of the losses and damage as well.

METHODS

The statistical data used in this report have come from two published reports relating to the damage to fishing vessels owing to accidents: Statistics of Fishing Vessel Insurance (hereinafter called the Insurance Statistics) and Report of Special Analyses on Accidents of Fishing Vessels Insured (hereinafter called the Special Report). The Insurance Statistics is issued annually, and the Special Report was compiled based on a detailed analysis of 1985 insurance data.

In the tables of the Insurance Statistics, damages sustained are classified according to those caused by bad weather such as heavy wind and rough seas, those caused by engine trouble such as a faulty lubrication system, those caused by human error in operating the ship and machines, those caused by drifting objects (this category is ambiguous but considered to be collision with drifting objects other than ice blocks), and those caused by foreign material tangled in the propellers. The cases to be discussed in this report will relate to damage caused by driftage, entanglement of foreign material in the propellers, and engine trouble resulting from trouble with the water cooling system.

Using the Special Report, more detailed analysis was possible. Accidents or trouble caused by drifting objects were classified into three categories: collision, cooling system trouble, and entanglement. As for the accidents or trouble with the cooling system, data indicating particular damaged points were also provided. As regards damage caused by drifting objects, the details given are those prepared especially for this report, obtained by reprocessing the original computer master tape used for the Special Report.

RESULTS

Fishing Vessel Insurance Statistics

Listed in Table 1 are the number of fishing vessels insured, the number of fishing vessels registered with the Fisheries Agency, the Government of Japan, and the percentage of insured fishing vessels (number of insured fishing vessels and number of registered fishing vessels). In

Table 1.--Number of fishing vessels registered, the number insured, and the ratio of vessels insured to total number of vessels (by gross tons (GT) and year) (Fishing Vessel Insurance Center 1985; Fisheries Agency of Japan 1975, 1982, 1983, 1984, 1985, 1986).

Vessels (GT)	1975	1982	1983	1984	1985	1986
			Number of fishing vessels registered (1)			
<5	316,683	363,875	364,620	365,207	364,197	361,838
5-20	19,397	28,038	28,216	28,304	28,343	28,488
10-50	2,555	1,574	1,436	1,361	1,243	1,105
50-100	4,022	3,640	3,523	3,372	3,016	2,764
100-1,000	3,223	3,312	3,325	3,302	3,272	3,222
Total	345,880	400,439	401,120	401,546	400,071	397,417
			Number of fishing vessels insured (2)			
<5	167,700	196,287	198,343	202,009	205,744	210,628
5-20	16,592	24,396	24,411	24,495	24,473	25,205
10-50	1,918	1,200	1,120	1,051	957	884
50-100	3,580	3,049	2,860	2,651	2,441	2,340
100-1,000	2,371	2,498	2,527	2,530	2,527	2,506
Total	192,161	227,430	229,261	232,736	236,142	241,563
			Ratio of vessels insured to total vessels (2)/(1)			
<5	0.530	0.539	0.544	0.553	0.565	0.582
5-20	0.855	0.870	0.865	0.865	0.863	0.885
10-50	0.751	0.782	0.780	0.772	0.770	0.800
50-100	0.890	0.838	0.812	0.786	0.809	0.847
100-1,000	0.736	0.754	0.760	0.766	0.772	0.778
Total	0.556	0.568	0.572	0.580	0.590	0.608

1986, of the vessels smaller than 5 GT, >200,000 units were insured, or 58% of all the registered fishing vessels of that size group. (All fishing vessels in Japan must be registered when they are built.) The percentage of insured fishing vessels of 5 GT and greater is as high as about 80%, even though the total number of such ships is much smaller than the number of ships of <5 GT.

Figure 1-1 and Figure 2 show the frequency of accidents and the average amount of damage per accident, respectively, for the driftage, floating ice blocks, entanglement of the propeller blades, and trouble with the engine cooling system based on the Insurance Statistics.

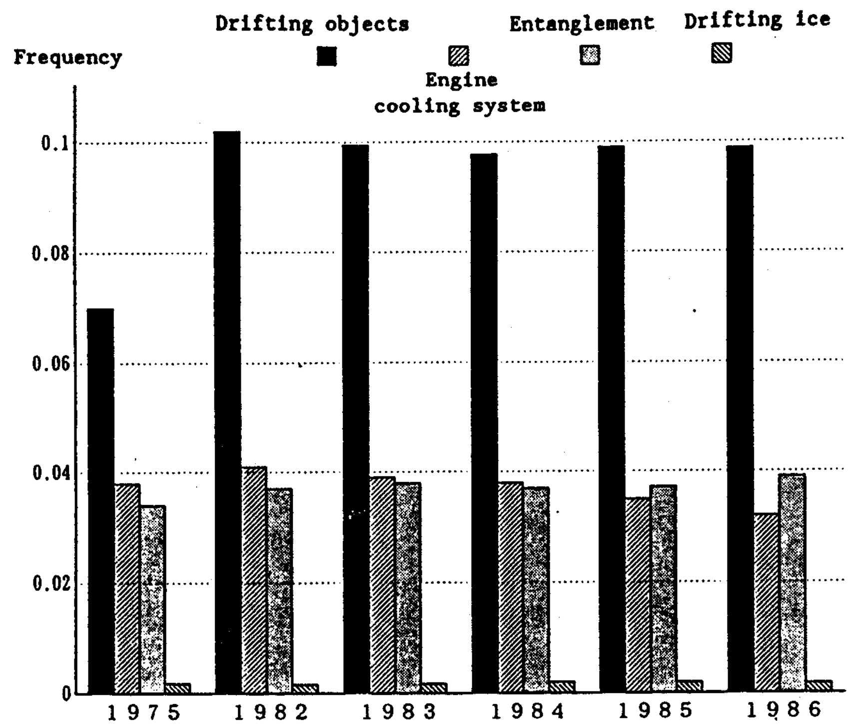


Figure 1-1.--Change in frequency of accidents (number of accidents/number of vessels insured) by type of accident. (Source: Statistics of fishing vessel insurance. Fisheries Agency of Japan.)

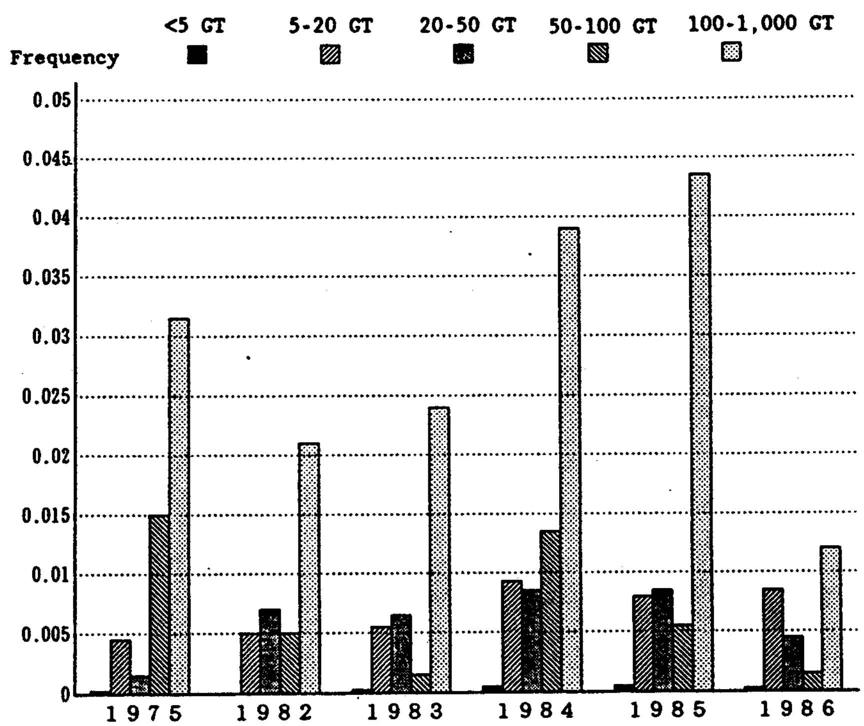


Figure 1-2.--Change in frequency of accidents caused by drifting ice blocks by size class of vessel. (GT = gross tons). (Source: Statistics of fishing vessel insurance. Fisheries Agency of Japan.)

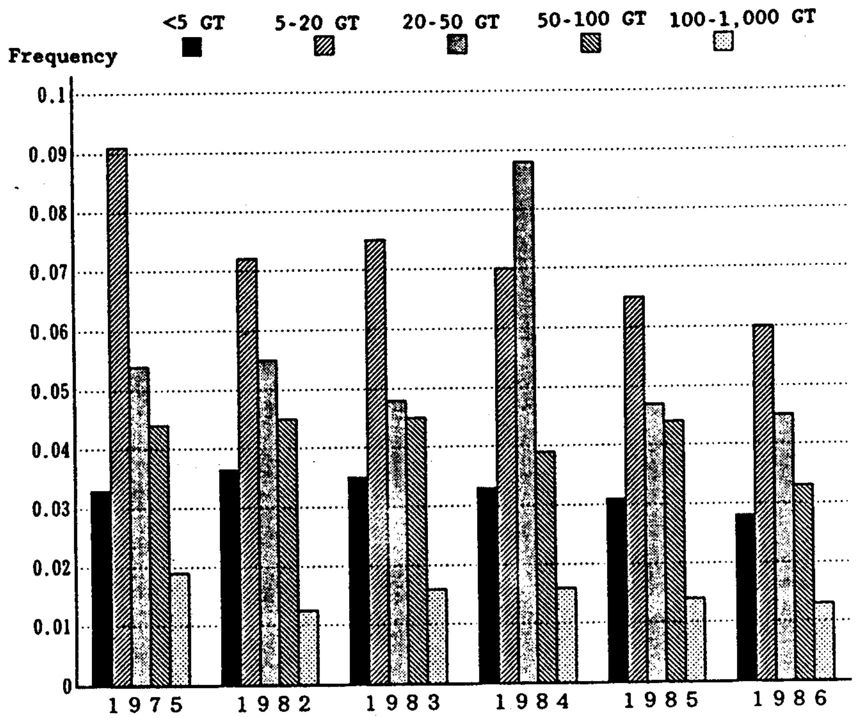


Figure 1-3.--Change in frequency of accidents or trouble with engine cooling system by size class of vessel (GT = gross tons). (Source: Statistics of fishing vessel insurance. Fisheries Agency of Japan.)

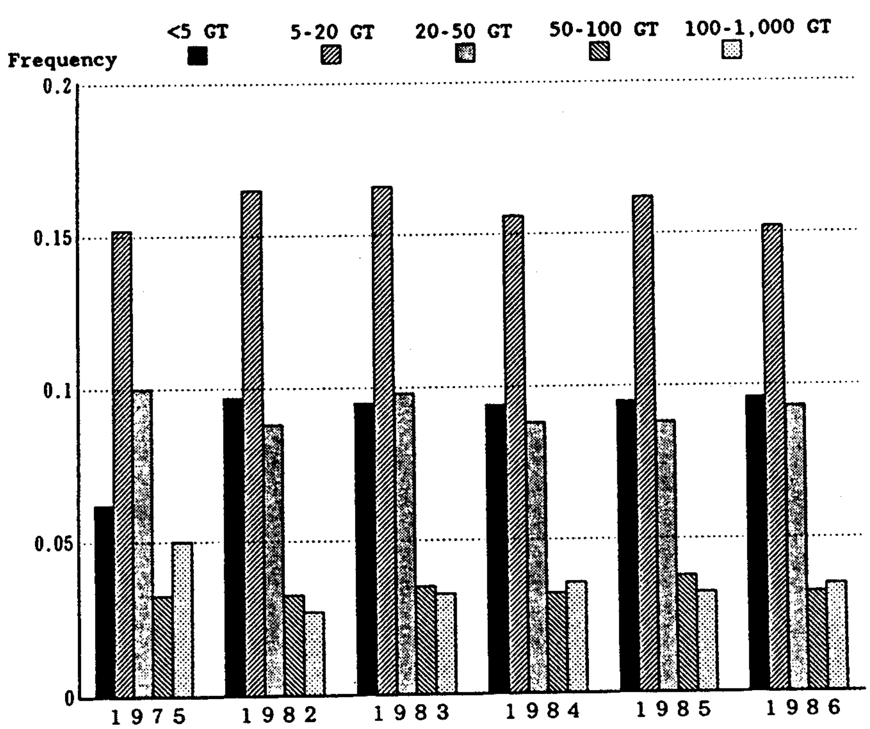


Figure 1-4.--Change in frequency of accidents caused by floating objects by size class of vessel (GT = gross tons). (Source: Statistics of fishing vessel insurance. Fisheries Agency of Japan.)

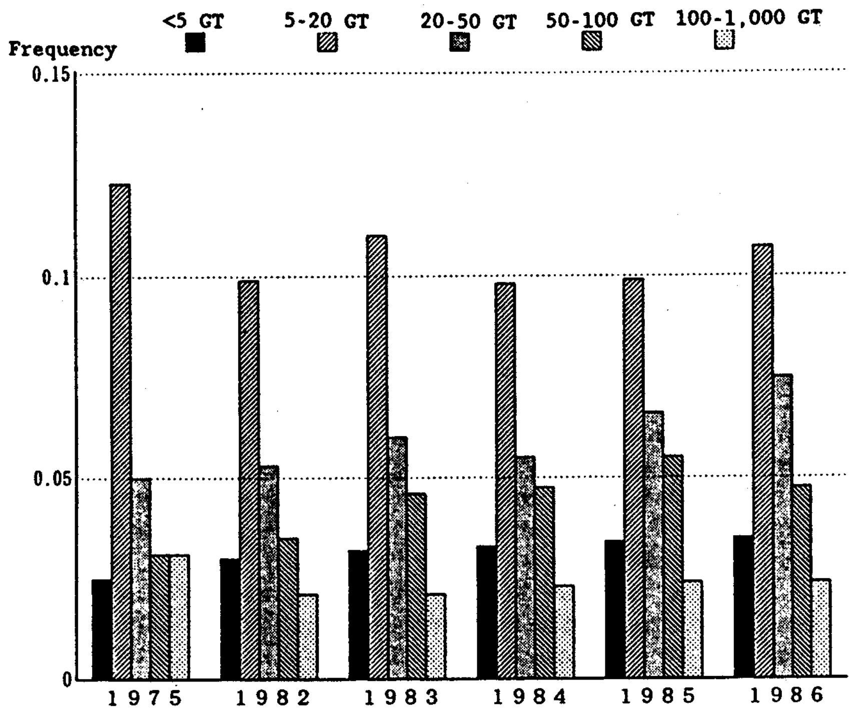


Figure 1-5.--Change in frequency of accidents caused by entanglement by size class of vessel (GT = gross tons). (Source: Statistics of fishing vessel insurance. Fisheries Agency of Japan.)

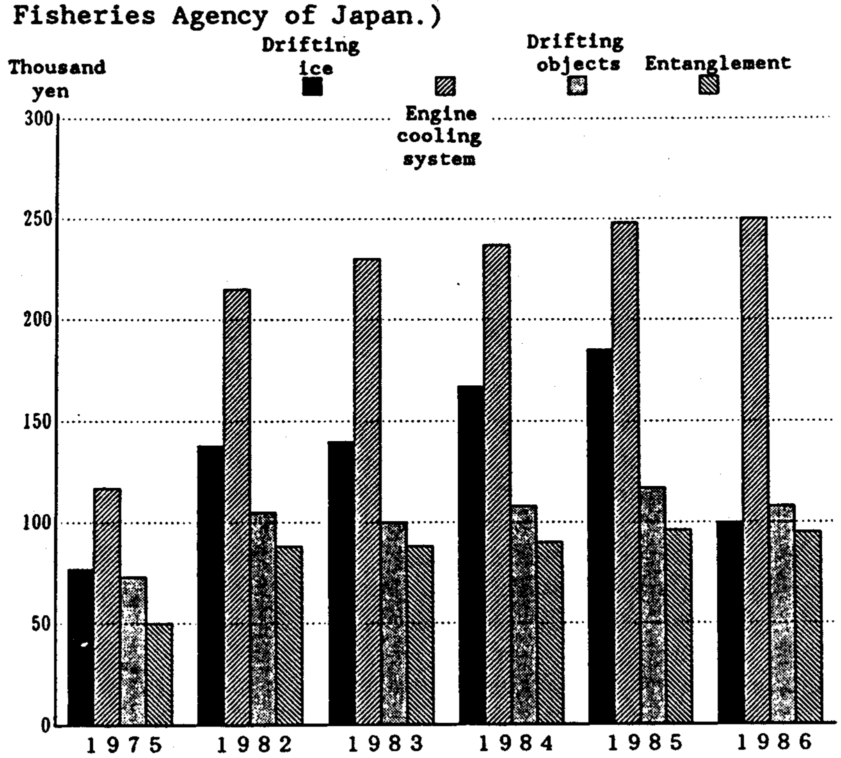


Figure 2.--Change in average cost of damage per accident by type of accident. Because the drifting ice category is so large, the cost shown in this figure has been divided by 10. (Source: Report of special analysis on accidents of fishing vessels insured. Fishing Vessel Insurance Center.)

The damage to the engine cooling system has a variety of causes including plastic bags. Damage by "drifting objects" has resulted from collision with objects floating in the sea, as described later. Damage by "entanglement" of fishing net and ropes in the propeller blades includes damage done not only by lost or discarded objects but also by fishing nets in actual use.

Except for damage done by "drifting objects," it was impossible to isolate the damage caused by only marine debris using the Insurance Statistics. These are, however, the only data available which enable us to review a historical change in accidents, and therefore, marine debris as a cause of the change is inferred by their use. In terms of frequency of accidents (number of accidents per number of fishing vessels insured), "drifting objects" is highest at about 10% (number of accident per number of insured vessels), which is more than twice the frequency attributable to other causes (Fig. 1-1). Conversely, the frequency of accidents is very low when it comes to the damage done by "floating ice," since such damage is limited to specific seasons and to specific areas of the sea. The frequency of accidents resulting from all categories shown has remained stable in the past 5 years. However, with regard to the accidents caused by drifting objects, this frequency is about 40% higher than it was in 1975, a percentage that has remained stable for the past 5 years.

Looking at the average cost per accident by type, "floating ice" stands out at ¥1 million or more suggesting that whereas its frequency of occurrence is low, the cost caused damage can be very great (Fig. 2). In contrast, accidents caused by drifting objects and entanglement in the propellers are low in cost, averaging around ¥100,000 per case.

With regard to differences in the frequency of accidents by size of fishing vessels, the frequency of "floating ice" is high in the case of ships of 100 GT or more, and is quite low with those of <5 GT. This is a natural consequence, because small ships rarely operate in a sea filled with drifting ice blocks during winter months (Fig. 1-2).

The frequency of accidents associated with the engine cooling system is highest for fishing vessels of 5-20 GT, next highest for those in the 20-100 GT class, and lowest for those of <5 GT. In any of these groups, the frequency of accidents tends to decline slightly over time (Fig. 1-3). The frequency of accidents caused by "floating objects," is highest with ships of 5 to 20 GT, followed by those of <5 GT and those 20 through 50 GT. It is the lowest with ships of 50 GT or larger. In most of those brackets, the frequency of accidents remains nearly the same. For vessels smaller than 5 GT, the frequency of accidents increased by 60% during the period from 1975 to 1982, and stabilized thereafter (Fig. 1-4).

In the entanglement of foreign materials in the propellers, too, the frequency is highest with vessels of 5 to 20 GT, followed by those <5 GT, 20 to 50 GT, and 50 to 100 GT. It is lowest with ships of 100 GT or larger. In terms of changes in frequency with time, ships in the of 20 to 50 GT and 50 to 100 GT classes are gradually increasing in number, whereas the frequency in the other brackets has remained stable (Fig. 1-5).

Special Report on Accidents of Insured Fishing Vessels

The purpose of the Special Report was to produce a detailed analysis based on data provided by the fishing vessel insurance. In order to do so, statements requesting payment were reprocessed to be collectively indicated on the form appearing in Figure 3. On this form, the types of accidents are classified (e.g., collision, fire, grounding, entanglement, engine trouble) as are the causes of the accidents (e.g., floating ice, drifting objects, inadequate watch), and by combining these categories, it is possible to determine the number of accidents of different kinds that were caused by floating objects and the cost as well. On the form, trouble with the engine cooling system is broken down into trouble resulting from plastic debris and that caused by other factors.

Accidents Caused by Floating Objects

Itemized in Table 2 by size of fishing vessel are the number of accidents classified by types of accidents caused by driftage and the amount of damage expressed in terms of money. Figures 4 and 5 show the frequency of accidents (the number of accidents divided by the number of insured fishing vessels) by type of accident and the average amount of damage per accident, respectively.

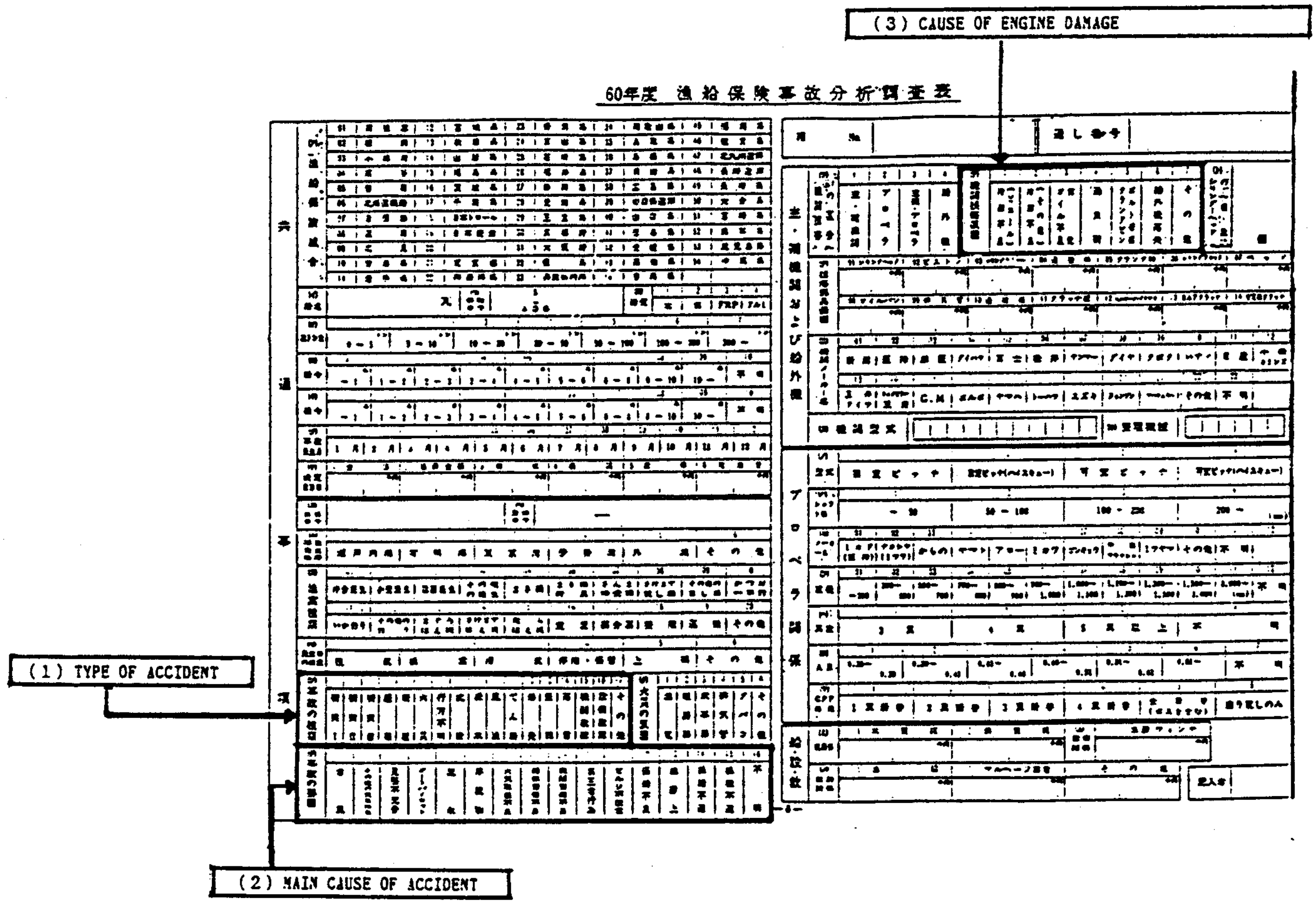
In 1985, there were a total of 32,8484 accidents resulting from drifting objects. There were 22,605 cases (69%) caused by collision, 5,809 cases (18%) with engine-related troubles, and 4,287 cases (13%) associated with entanglement. One hundred and forty-seven cases did not fall under any such classification (Table 2).

The cost of damage totaled ¥4.4 billion. It is said, in general, that the average such cost goes up as the size of the ship becomes larger. With ships <20 GT, the cost associated with engine trouble is the highest, and in the case of larger ships, the cost resulting from collision is the highest (Fig. 5).

In all size categories, accident frequencies are highest for those caused by collision, whereas the frequencies are lowest for engine trouble in all but the smallest ship size bracket. The frequency for the 5-20 GT category is highest in all types of accidents, whereas the frequency is low for size brackets of 50 GT or more, except for entanglement of foreign material in the propellers. The frequency of such entanglement is relatively high for 50 to 100 GT vessels, and low for those of <5 GT (Fig. 4).

Comparison of Accidents Caused by Marine Debris With Those of Other Causes

Figure 6 shows accidents caused by floating objects as a percentage of all accidents, by type of accident. The causes other than the driftage include entanglement with the fishing gears in actual use in the category of entanglement, and collision with submerged rocks in the category of collision. Collision as referred to here does not include ship-to-ship collision or grounding.



(1) Type of accident	(2) Main cause of accident	(3) Cause of engine damage
Collision with ships	Typhoon	Insufficient cooling resulting from clogging with plastic film.
Collision with ice blocks	Other weather phenomenon	Insufficient cooling from other causes.
Collision with others	Inadequate watch	Insufficient oil or deteriorated oil.
Grounding	Autopilot system	Overload.
Capsizing	Floating ice	Breakage of crank pin or bolt.
Fire	Floating objects other than ice	Dropping of outboard engine.
Missing	Careless handling of fire	Other.
Sinking	Improper ship maintenance	
Water intrusion	Improper machine maintenance	
Damage by rough sea	Intentional damage by others	
Entanglement	Improper ship mooring	
Explosion	Improper fishing operation	
Theft	Improper ship operation	
Damage by lightning	Improper machine operation	
Engine trouble	Other	
Machine trouble		
Other		

Figure 3.--Compilation form for the Special Report.

Table 2.--Number of accidents and damage caused by marine debris by type of accident and by vessel size (gross ton (GT)). (Number is actual number, and amount of total damage and damage per accident are shown in ¥1,000.) (Fishing Vessel Insurance Center 1985; Fisheries Agency of Japan 1975, 1982, 1983, 1984, 1985, 1986.)

Accident or damage	Vessels 0-5 GT			Vessels 5-20 GT			Vessels 20-50 GT		
	Number	Damage	D/N[a]	Number	Damage	D/N[a]	Number	Damage	D/N[a]
Collision	18,644	1,639,473	87.9	3,715	626,365	168.6	78	102,718	1,316.9
Entanglement	2,852	192,917	67.6	1,279	159,982	125.1	44	18,244	414.6
Engine trouble	4,773	814,839	170.7	940	363,436	386.6	35	20,521	586.3
Other	94	16,962	180.4	42	22,881	544.8	5	4,799	959.8
Total	26,363	2,664,191	101.1	5,976	1,172,664	196.2	162	146,282	903.0

Accident or damage	Vessels 50-100 GT			Vessels 100-1,000 GT			Total all vessels		
	Number	Damage	D/N[a]	Number	Damage	D/N[a]	Number	Damage	D/N[a]
Collision	90	132,083	1,467.6	78	158,264	2,029.0	2,605	2,658,903	117.6
Entanglement	82	26,217	319.7	30	40,153	1,338.4	4,287	437,513	102.1
Engine trouble	48	46,613	917.1	13	17,045	1,311.2	5,809	1,262,454	217.3
Other	2	862	431.0	4	30,557	7,639.3	147	76,061	517.4
Total	222	205,775	926.9	125	246,019	1,968.2	32,848	4,434,931	135.0

[a]Damage divided by number.

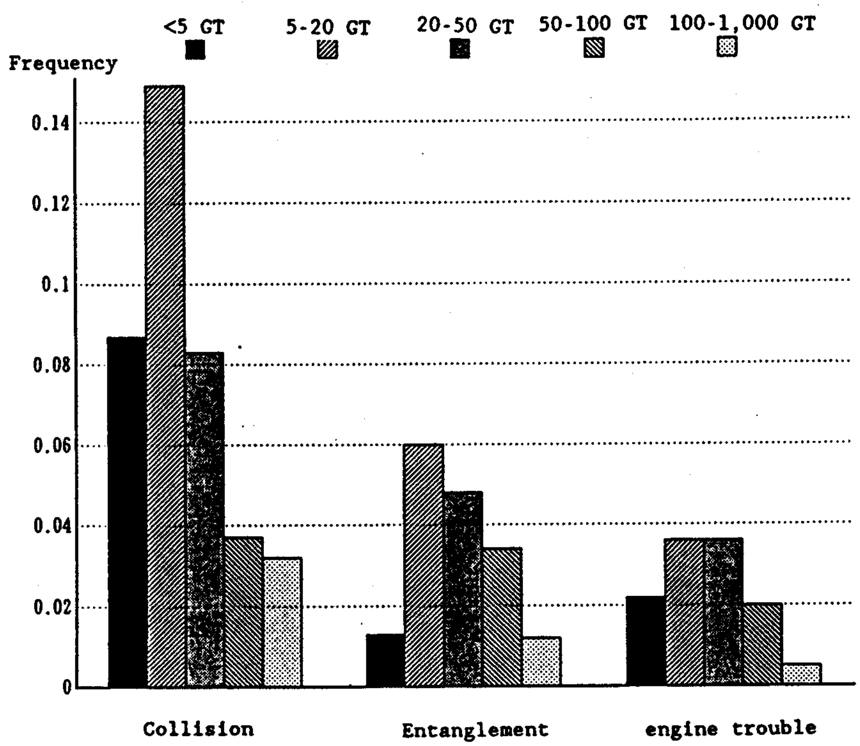


Figure 4.--Frequency of accidents caused by floating objects by type of accident and by size class of vessel (GT = gross tons). (Source: Report of special analysis on accidents of fishing vessels insured. Fishing Vessel Insurance Center.)

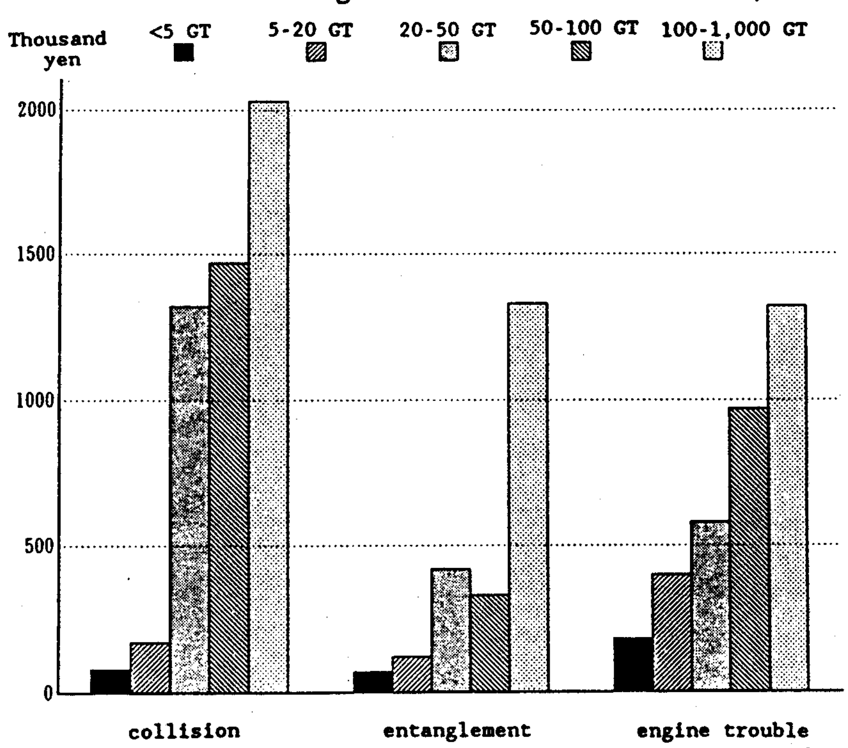


Figure 5.--Average cost of damage per accident caused by floating objects by type of accident and by size class of vessel (GT = gross tons). (Source: Report of special analysis on accidents of fishing vessels insured. Fishing Vessel Insurance Center.)

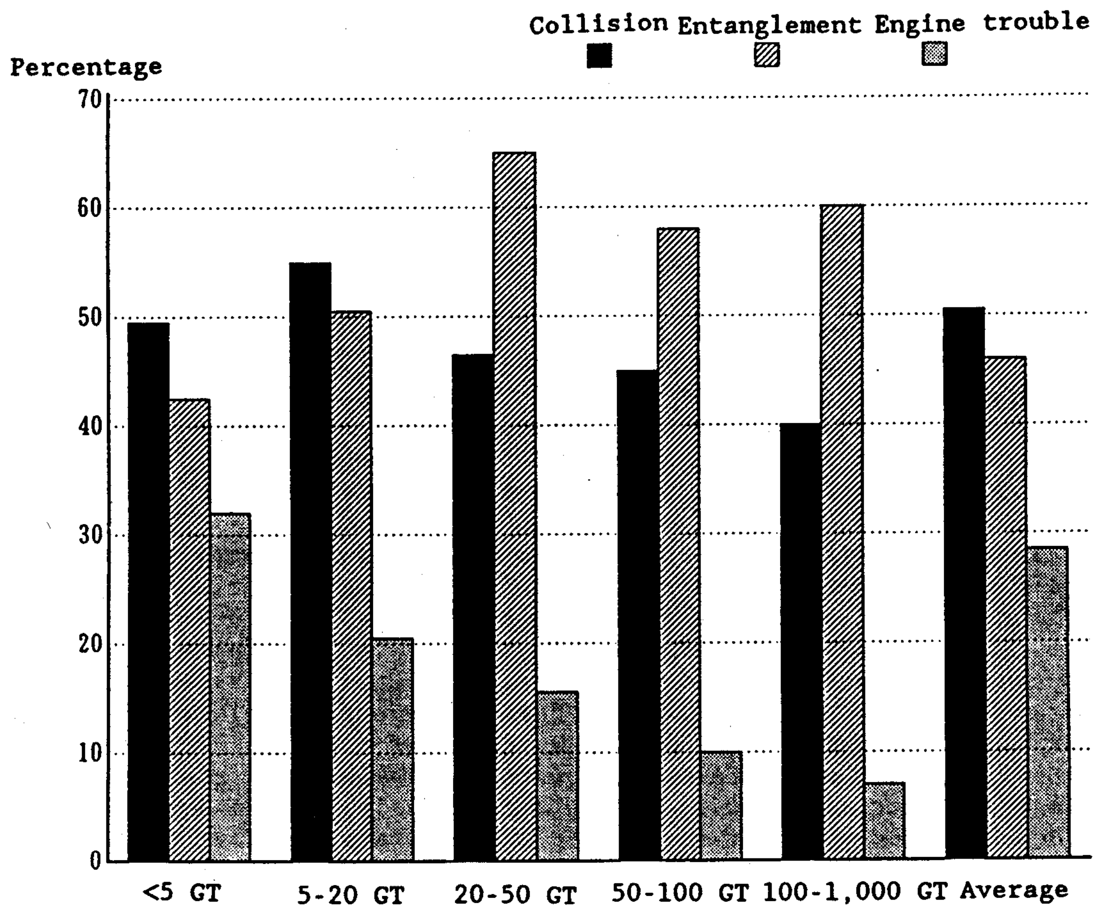


Figure 6.--Percentage of the number of accidents caused by floating objects in relation to total number, by type of accident, and by size class of vessel (GT = gross tons). (Source: Report of special analysis on accidents of fishing vessels insured. Fishing Vessel Insurance Center.)

Percentagewise, engine trouble caused by floating objects is low on the whole, and the percentage decreases in reverse proportion to the size of ships.

For vessels <50 GT, the percentage of entanglement trouble caused by driftage increases with vessel size, but with the vessels >50 GT, the percentage tends to decrease.

In cases of collision, the percentage is the highest for vessels in the 5 to 20 GT category, and decreases as vessel size becomes larger.

It may be generalized that the percentage of damages attributable to drifting objects is lower in reverse proportion to the size of ships (Fig. 6).

Accidents or Trouble With the Engine Cooling System

The Special Report gives statistical data detailing the number of accidents or engine trouble and the amount (in yen) of damage resulting from improper engine cooling caused by plastic debris clogging the cooling water intake.

In 1985, there were 2,576 accidents with damage to engine cooling systems caused by plastic debris, which were covered by insurance. The cost of damages totaled ¥614 million. The frequency of accidents and the average cost per accident causing damages to the engines are shown in Figures 7 and 8, respectively. In those figures, causes of damage to the cooling system by other than plastic debris are added for reference. The frequency of accidents caused by plastic debris is lower for fishing vessels of larger size with the exception of those <5 GT. The average damage, on the other hand, increases with large ships.

There is slightly more engine trouble caused by factors other than plastic debris than trouble attributable to plastic debris, by size group of fishing vessels. The specific cause of these other accidents is not known. The cost per accident is nearly equal to or somewhat lower than that caused by plastic debris. According to Usui of the Fishing Vessel Insurance Center, who compiled the Special Report trouble with the cooling water systems occurs frequently as a result of clogging of the inlet ports for cooling water with drifting objects such as wood or grass. Since the average cost per accident is nearly the same, it is conceivable that accidents caused by other than plastic debris are similar to those caused by plastics. This seems to support Usui's statement.

Figure 9 shows the locations of main damage to the engines caused by a deficiency of the cooling system, which in turn was caused by plastic debris, as clarified in the Special Report. The damages to cylinder heads accounted for 57%; cylinder liners, 19%; and pistons, 14%.

DISCUSSION

The data of the Special Report differ somewhat from the Insurance Statistics for 1988. According to the Insurance Statistics, the number of insured vessels is 236,142, whereas the number given in the Special Report is 245,826, greater than the former by 9,700 ships or 4%. This difference is mostly in small ships, and therefore does not seem to adversely affect a comparison between the two sets of data.

As shown in Figure 10, in comparing the frequencies of accidents caused by collision with floating objects (category "floating objects" from the Insurance Statistics and "collision with floating objects" from the Special Report), they were found nearly the same in all ship size brackets.

The frequency of "entanglement" accidents given in the Insurance Statistics coincides well with the frequency of "entanglement" accidents in the Special Report. The frequency of "floating debris-related entanglement" in the Special Report is much lower when compared to the

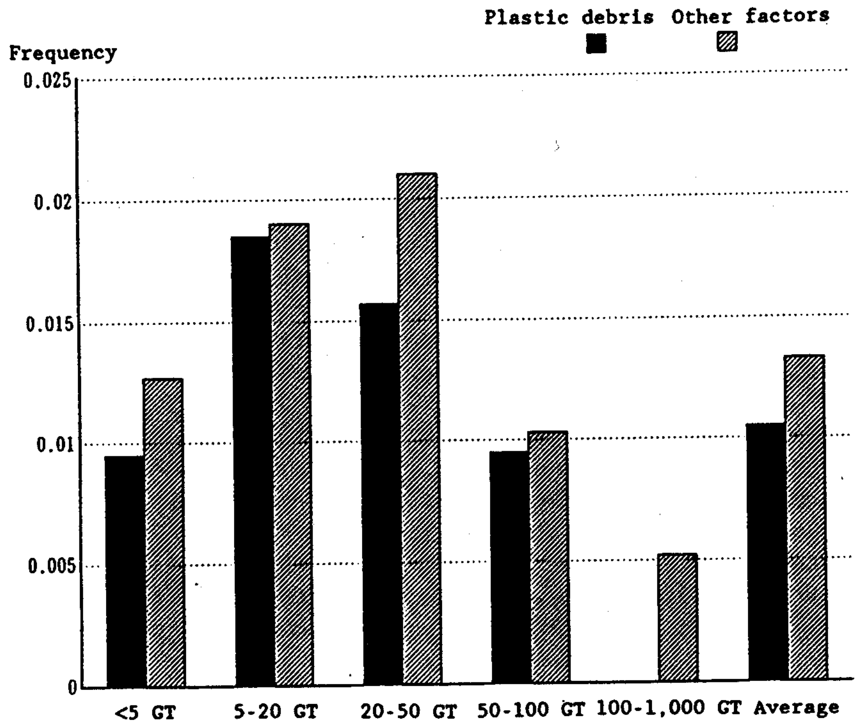


Figure 7.--Frequency of accidents of engine trouble caused by plastic debris and other factors by size class of vessel. (Source: Report of special analysis on accidents of fishing vessels insured. Fishing Vessel Insurance Center.)

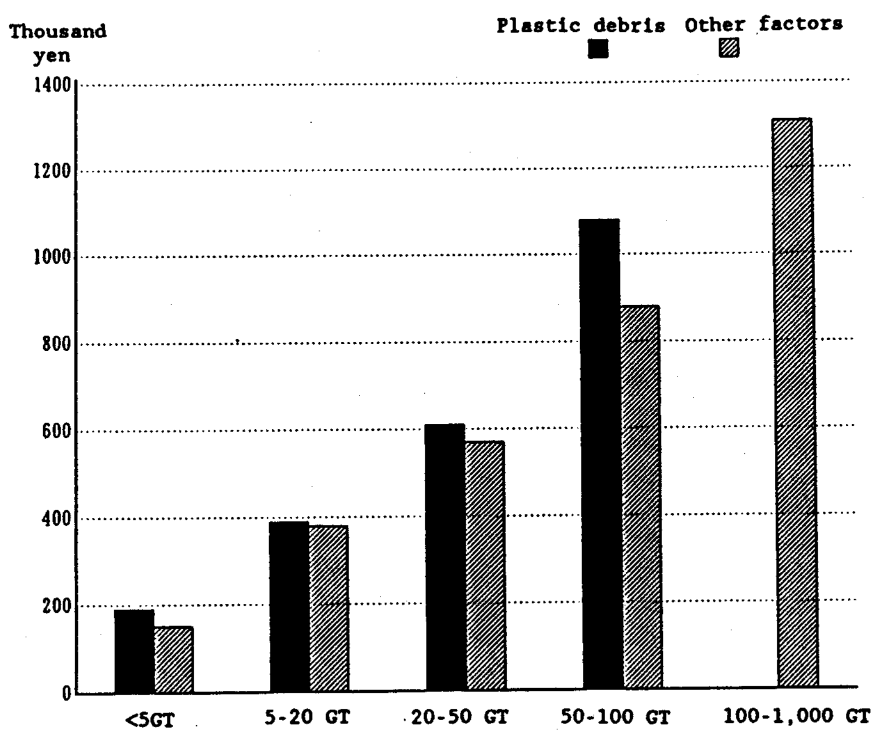


Figure 8.--Average cost per accident of engine trouble caused by plastic debris and other factors by size class of vessel. (Source: Report of special analysis on accidents of fishing vessels insured. Fishing Vessel Insurance Center.)

other two (Fig. 11). Because of this, "drifting objects" in Figure 1-1 represents changes in frequency of collisions with objects drifting in the sea, and "entanglement" in the same figure includes those accidents caused by other than floating debris, as previously stated. Further, Figure 11 shows that the percentage of entanglement accidents caused by other than floating debris becomes lower as the vessels become larger, when compared to entanglement accidents caused by floating debris. This is understandable, because human activities including fishing are much higher in the coastal areas than farther offshore and opportunities of encountering mooring ropes or fishing nets in actual use are greater in coastal waters. The density of marine debris distribution also lessens in the offshore waters.

The Special Report indicates that the frequencies of all three types of accidents (collision, entanglement, and engine trouble) show the same tendency, becoming lower as the vessel size become larger with the exception of vessels of <5 GT (Fig. 4). Such results are understandable, because the distribution density of drifting objects is high in the coastal waters in general, and small ships tend to operate in the vicinity of the coast. Several reasons can be conceived for the low frequency of accidents involving ships <5 GT. These are:

- Many boats with outboard engines are included in this category and their engine and water intake are easy to monitor, making it easier to detect the start of trouble such as trouble with the cooling system.
- Small vessels rarely operate at night.
- Small vessels are easier to monitor adequately than larger vessels.

According to the Special Report, the amounts of damages covered by insurance and resulting from collision, entanglement, engine trouble, and other accidents associated with objects floating in the sea were ¥2,659 million, ¥437 million, ¥1,262 million, and ¥76 million, respectively, for a total of ¥4,435 million. The total amount of such damage for all vessels in 1985 is estimated to be ¥6,608 million, a figure determined by extrapolation using ratios of the number of insured ships to the number of fishing vessels that were registered, by size (tonnage).

The estimated figure, however, is considered to be an overestimation. It is unrealistic to think that all the fishing vessels registered actually operated in that year. (Some are not in use any more and have not yet been removed from the register.) However, there are no statistics covering the number of fishing vessels that did operate during 1985. Furthermore, the statistical data used may have some problems in their characteristics since they were not prepared for this type of analysis, but they are considered to be pretty reliable. The actual size of the damage is thought to be somewhere between ¥4.4 billion and ¥6.6 billion. Such an amount is so huge that it calls for some review to determine its appropriateness. The total fishery production in 1985 by fishery management units with vessels of

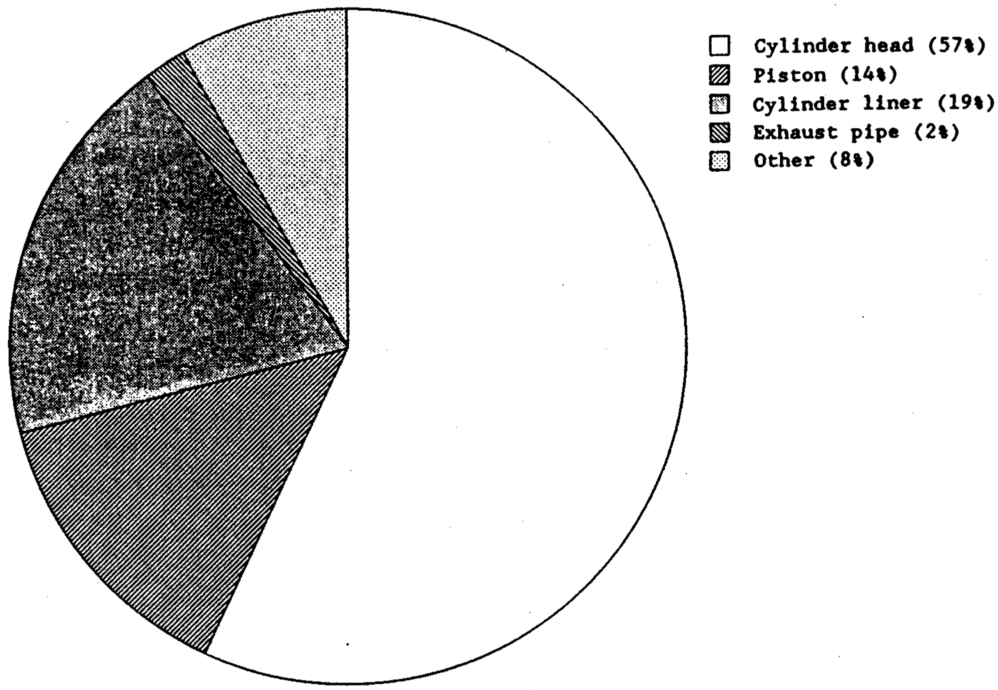


Figure 9.--Engine part which is reported as damaged most severely in an accident of engine trouble caused by plastic debris. (Source: Report of special analysis on accidents of fishing vessels insured. Fishing Vessel Insurance Center.)

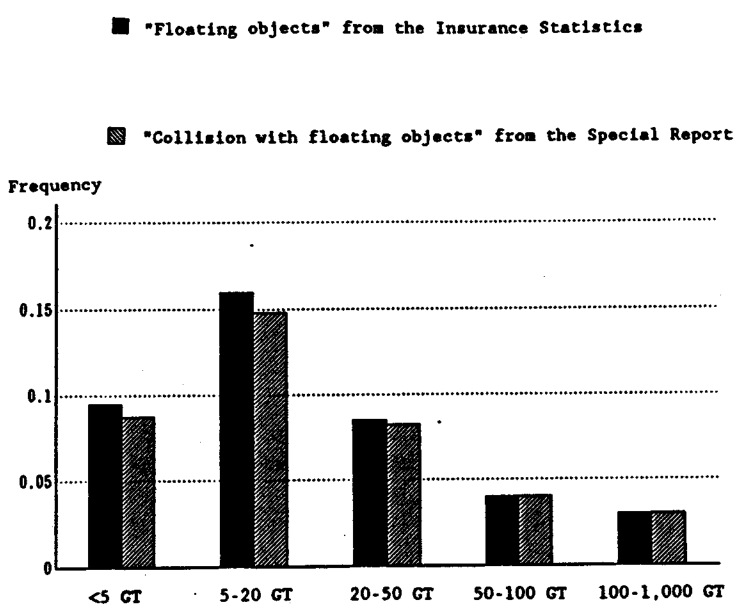


Figure 10.--Comparison of frequencies of accidents caused by "floating objects" from the Insurance Statistics, and "collision with floating objects" from the Special Report. (Source: Report of special analysis on accidents of fishing vessels insured. Fishing Vessel Insurance Center.)

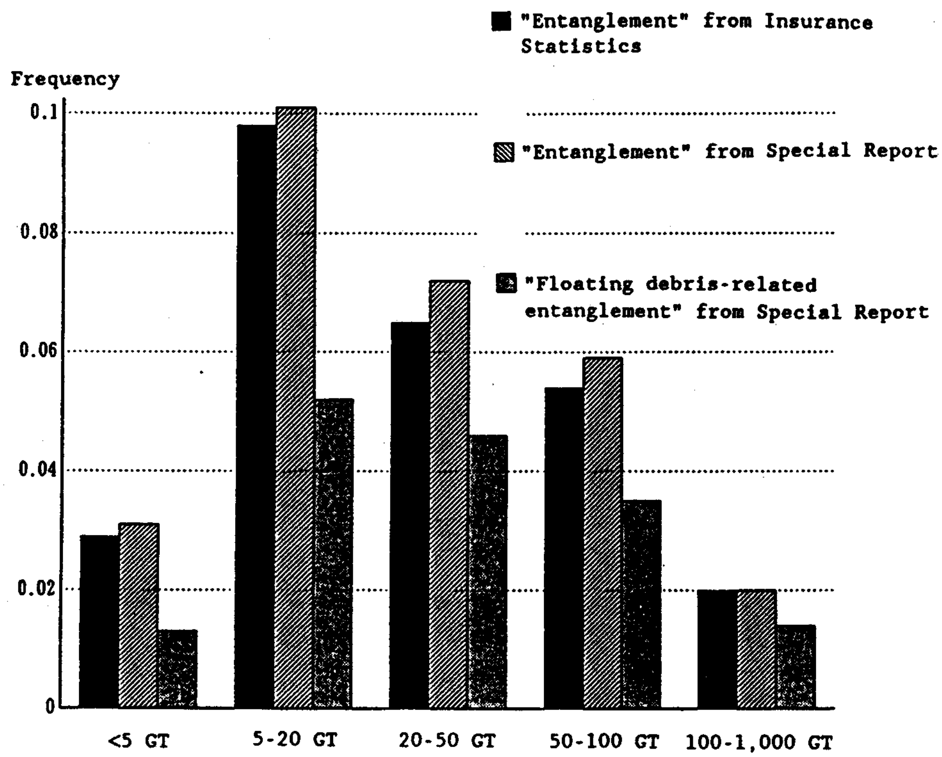


Figure 11.--Comparison of frequency of entanglement accidents. (Source: Report of special analysis on accidents of fishing vessels insured. Fishing Vessel Insurance Center. Statistics of fishing vessel insurance. Fisheries Agency of Japan.)

<1,000 GT was ¥2,165 billion. Realizing that the cost of running the fishing business in general is roughly 90% of the sales, and the total output is ¥1,949 billion, therefore damages costing ¥6.6 million, or 0.3% of the above-mentioned figure, do not seem to be unrealistic. It is, however, based solely on the available statistical data. No study has yet been made of the system used in the operation of the insurance, including confirming of the accidents. Also, no study has been made of the available ship accident reports. I invite comments and opinions from those involved in the Japanese fishing vessel insurance system.

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NEW YORK STATE MARINE DEBRIS PROGRAM

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ABSTRACT

New York State has a multifaceted approach to prevention of marine debris. Regarding the sources of infectious waste-related debris, the state issued jointly with New Jersey a series of similar regulations which provided for a manifest tracking system. The state also recently passed additional legislation which increases the penalties for illegal disposal and removes the small quantities generator exemption; an additional US$2 million was earmarked for enforcement.

The program to prevent the major portion of debris continues. The Department of Environmental Conservation works with Federal and local agencies to minimize contribution from such sources as combined sewer overflows and solid waste handling. The department also works with local environmental groups, education institutions, and the marine trades association in a public awareness campaign. The conclusions drawn from documented cleanups at eight beaches during Beach Cleanup Day, 8 October 1988, are discussed.

In R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

MEDICAL WASTES AND THE BEACH WASHUPS OF 1988: ISSUES AND IMPACTS

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ABSTRACT

The beach washups of medical wastes in 1988 resulted in beach closings, even if the extent of public health hazard posed by these wastes is not known with certainty. The nature and extent of economic impacts of the closings to the Long Island and New Jersey areas are assessed, based on available information.

Investigations to determine the sources of medical waste and other floatable marine debris along the shores of New York City, Long Island, and other nearby coastlines find that the primary sources are the Fresh Kills landfill (including barges transporting waste to it), marine transfer stations, combined sewer overflows, raw sewage discharges, and storm water outlets. Other sources, such as illegal dumping, probably contribute a smaller portion of floatables. This has important implications for whether some types of laws and programs being proposed and adopted, such as a manifest tracking system, will adequately address the problem of beach washups.

OVERVIEW

On 23 May 1988, a garbage slick nearly a mile in length along the shore of Ocean County, New Jersey, marked the season's first major washup of marine debris. Needles, syringes, and empty prescription bottles with New York addresses were among the floatable marine debris washed ashore. Beaches were closed as a result of this and similar incidents, including closing of more than 24 km (15 mi) of Long Island beaches from 6 to 8 July.

In R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

Throughout the summer of 1988, national attention focused on reports of beach washups of medical wastes at various locations in the United States, much of the attention being given to washups on the east coast.

The east coast washups actually were about 10% or less "medical-related" waste. The largest single medical-related floatable was the insulin-type disposable syringe (New York State Department of Environmental Conservation (NYSDEC) 1988). Misconceptions about the quantities and nature of medical wastes washed ashore apparently resulted in part from the misidentification of items and from inaccurate media reports.

The degree of risk posed by medical wastes is not known. Proper handling, treatment, and disposal of these wastes are believed to minimize human health and environmental risks. Yet incidents resulting from careless or illegal disposal do pose aesthetic problems, and certainly help create public apprehension over current medical waste management practices. Aesthetic degradation and possible adverse health effects from medical wastes on public beaches are impacts difficult to measure and assess directly. Economic impacts resulting from the washups may be a more direct measure of their importance.

First, it is useful to define medical wastes and look at the broader context within which they are generated, managed, and regulated. Medical wastes include all infectious waste, hazardous (including low-level radioactive) wastes, and any other wastes generated from all types of health care institutions, including hospitals, clinics, doctors' (including dental and veterinary) offices, and medical laboratories (Lee 1988). The main focus of concern has been on the portion of medical wastes that are defined as infectious or "red bag" wastes, and how they are classified (e.g., as a solid, hazardous, or "special" waste) and regulated. The Centers for Disease Control and the U.S. Environmental Protection Agency (EPA) both designate as infectious pathological waste blood and blood products, contaminated sharps, and microbiological wastes (U.S. Congress 1988). The main sources of these wastes receiving attention are hospitals and other large facilities, but other sources of infectious wastes, such as sewage overflows, can also be significant contributors of environmental contamination.

The EPA reports that approximately 3.2 million tons of medical wastes from hospitals are generated each year, or about 2% of the total municipal solid waste stream. Currently, most generators of medical waste designate between 10 and 15% of it as infectious. The NYSDEC estimates that approximately 315 tons of medical wastes a day are generated by New York City's (NYC) 75 hospitals; and of this about 63 tons is infectious waste (NYSDEC 1988). Most of the medical waste washed ashore in the Greater NYC, Long Island, New Jersey, and even Rhode Island coastal areas is presumed to have emanated from the Greater NYC area. The actual amount of waste which washes ashore is not known with certainty, but is regarded as a large volume (NYSDEC 1988). At times, in some locations two pieces of medical debris per mile are found, while during a "garbage slick," garbage bags full of medical waste can be collected (NYSDEC 1988; Associated Press 1989).

Most infectious waste from hospitals is incinerated, while most noninfectious medical waste is landfilled. However, just as beach wash-up incidents raise public concern over current medical waste management practices, considerations of liability and worker safety lead some operators of municipal solid waste landfills and incinerators to refuse to take any medical wastes. As medical waste management becomes increasingly problematic for these types of reasons, an additional concern becomes the increased potential for illegal disposal.

The situation is further complicated by an uncertain and incongruous regulatory climate. Inconsistencies exist in the Federal guidelines for states regarding definitions and management options suggested for medical and infectious waste. Currently, no Federal regulations exist that comprehensively address the handling, transportation, treatment, and disposal of medical waste. This could change if the issue of medical wastes remains part of the current reauthorization effort for the Resource Conservation and Recovery Act (RCRA) or if the demonstration program of the Medical Waste Tracking Act (MWTA 42 U.S.C. 6901 et seq.) is expanded and extended in the future. As will be discussed below, other, specific types of management and enforcement actions may best address the issue of medical waste in beach washups. The Office of Technology Assessment (OTA), as part of a larger assessment of municipal solid waste, issued a separate background paper on medical waste management in October 1988 (U.S. Congress 1988). Reference should be made to that paper for a more detailed overview of medical waste management issues.

POSSIBLE ECONOMIC IMPACTS

The beach washups of 1988 in the Long Island and New Jersey areas had potential economic impacts of both revenue losses and costs. Revenue losses to the travel and tourism industry can result from declines in beach use, recreational fishing, and use of charter and party boats (R. L. Associates and U.S. Travel Data Center 1988; Thomas Conoscenti & Associates 1988; Ofiara and Brown 1989). Other possible economic impacts include increased beach maintenance and surveillance costs.

The focus here, based on very limited available information and in light of important caveats, is on the possible revenue losses to travel and tourism. Available information is suggestive of the types of short-term economic impacts which may be associated with the beach washups of 1988. It should be emphasized, however, that the information is not conclusive; some of it is anecdotal, most of the estimates of revenue losses are based on limited data (at most, for 2 or 3 years), and longer-term trends were not taken into account.

Causal links between the changes in beach use and tourism patterns and the beach washups and closings have not been carefully established, but are assumed in the estimates cited. Further, the methods used to estimate the changes and their impacts are not highly rigorous. Valid comparisons between losses to both New Jersey and Long Island coastal communities cannot be made given the different techniques used to estimate revenue losses.

The Long Island Tourism and Convention Commission reported a decline of 18% (i.e., an estimated 4.6 million fewer persons) in beach attendance in 1988 compared to 1987, and attributes this to the beach closings (Thomas Conoscenti & Associates 1988; Fey 1989). The commission also noted a decrease in attendance at all resorts and beaches (whether closed or not) as a result of the beach closings. Not surprisingly, decreased spending accompanied the lower beach attendance (Table 1). The difference between the 1987 tourism base and the estimated actual 1988 tourism base was $921.2 million. The commission, however, calculated an estimated net loss of $1.4 billion due to the beach closings in 1988, comparing the actual estimated tourism base of 1988 with that of an estimate of the industry base if it had grown in 1988 at the historical rate of 5.6% (Thomas Conoscenti & Associates 1988). The commission also reported that the actual net effect was likely to be considerably less than $1.4 billion since it could be assumed that some of the tourists who did not visit the beaches probably participated in other activities on Long Island.

One part of the tourism and travel industry which may not be reflected in the calculations of the commission's survey (but is included in the marine recreational fishing category of the New Jersey estimates discussed below) is the charter and party boat businesses. A survey of NYC and Long Island charter and party boats owners found a 30 and 26% decline, respectively, in the number of passengers carried and trips conducted in 1988 compared to previous years (reportedly from 1985 through 1987) (DiLernia and Malchoff 1989). Floatables, including medical wastes, were considered by 60% of the party boat captains to be the most important issue affecting their business in 1988. Yet the respondents also agreed that a number of other factors threaten the profitability of the boat businesses, such as general marine pollution, a drop in fish stock abundance, and the high cost of operating vessels (DiLernia and Malchoff 1989).

One preliminary analysis of the impacts of the beach washups on all the beach towns in Monmouth, Ocean, Atlantic, and Cape May Counties, New Jersey, found that the overall range in beach attendance decrease from 1987 to 1988 was 7.9 to 34% (Ofiara and Brown 1989). (It should be noted that these investigators are completing their investigation and a more detailed version of their results will be available in April 1989.) Each of the four coastal counties experienced beach closings in 1987, but the beach attendance decrease between 1986 and 1987 ranged from 8.9 to 18.7%. The survey also indicated a 58% decline in beach attendance from 1985 to 1988 reported by seven New Jersey communities (Ofiara and Brown 1989).

According to the New Jersey Division of Travel and Tourism, an estimated 1.9 million fewer persons visited the New Jersey shore in 1988 than in 1987, a 22% drop in attendance (R. L. Associates and U.S. Travel Data Center 1988). In a 1988 survey of visitors, 22% considered themselves less likely to visit the New Jersey shore in 1989, with approximately the same number of respondents in this category as in 1987. Forty-four percent of this group of respondents identified pollution as their number one reason for not returning in 1989 (R. L. Associates and U.S. Travel Data Center 1988). (Pollution was in fact the single biggest reason given by those who indicated they would not be returning the following year to the New Jersey shore. This is a 10 percentage point increase over those who

Table 1.--Tourist and convention expenditures. Total Long Island, 1987 and 1988. (Source: Thomas Conoscenti & Associates, Inc. 1988.)

Visitors and their expenditures	1987	1988	Difference
Tourist and convention visitors (millions)	25.5	20.9	4.6
Expenditures (millions $)			
-Lodging[a] [b]	368.9	332.2	36.7
-Food[c]	1,147.5	1,003.2	144.3
-Transportation[d]	255.0	219.5	35.5
-Entertainment	561.1	505.3	55.8
-Other[e]	1,009.2	908.8	100.4
Total	3,341.7	2,969.0	372.7
Annual total impact (millions $)	7,685.9	6,828.7	857.2
Other direct summer activity (millions $)[f]	589.0	525.0	64.0
Total tourist/convention industry (millions $)	8,274.9	7,353.7	921.2

[a]Based on 14,000 rooms.
[b]Average lodging rate (1987 - $95/night; 1988 - $100/night).
[c]Average $45/day in 1987 and $48/day in 1988.
[d]Includes day trips.
[e]Other - e.g., retail sales.
[f]Visitors to homeowners in summer.

had indicated in a survey the year before that they would be less likely to visit the shore in 1988 due to pollution. Yet about the same percentage (50% in 1987 and 47% in 1988) indicated that they were as likely to visit the shore the following year.)

The division also reports that a 9% decline in total expenditures occurred in 1988 at the New Jersey shore, a loss of approximately $745.6 million. A more extensive analysis of revenue losses sustained by recreational fishing, beach use, and travel and tourism combined finds total estimated losses to range from $545.9 million to $2,022.85 million and, with all indirect effects included, to range from $820.7 million to $3,060.8 million (Ofiara and Brown 1989; Table 2).

It should be stressed again that these calculations are not comparable given the different methods used to derive them, and that the bases for them may be imprecise and have not been evaluated by the OTA. Yet, even with these qualifications, it appears that revenue losses have occurred. And it seems reasonable to assume that part of these losses was due to changes in beach use, recreational fishing and boating, and travel and tourism patterns which seem to have resulted primarily from the beach closings of 1988.

Table 2.--Aggregate estimated economic impacts to beach use, travel and tourism, and marine recreational fishing, New Jersey, 1988. All dollars are in 1987 dollars. (Source: Ofiara and Brown 1989.)

Category[a]	Trips (No.)	Economic benefits	Expenditures ($1,000,000)	Gross value
Beach use				
Minimum	5,763,200	117.61	223.07	340.68
Maximum	24,493,600	499.83	948.05	1,447.87
Multiplier impacts				
Minimum		117.61	423.61	541.22
Maximum		499.83	1,800.35	2,300.18
Travel and tourism				
No. of businesses affected				
Minimum				395
Maximum				1,699
No. of lost jobs				
Minimum				9,553
Maximum				14,114
Lost wages ($)				
Minimum				34.34
Maximum				147.79
Recreational fishing				
Minimum	1,332,600	88.28	82.60	170.88
Maximum	3,331,500	220.69	206.50	427.19
Multiplier impacts				
Minimum		88.28	156.86	245.14
Maximum		220.69	392.15	612.84
All activities				
Minimum		205.89	305.67	[b]545.90
Maximum		720.52	1,154.55	[b]2,022.85
Multiplier impacts				
Minimum		205.89	580.47	[b]820.70
Maximum		720.52	1,154.55	[b]3,060.80

[a]Minimum refers to the minimum of the range. Maximum refers to the maximum of the range. Multiplier impacts are derived from the product of expenditures times 1.899; the New Jersey State multiplier associated with net output (includes value added), plus economic benefits.

[b]The sum of benefits, expenditures, and lost wages.

Even more limited information exists on the actual or estimated dollar impacts of various economic costs than on revenue losses for travel and tourism. For example, New Jersey spends approximately $3 million annually on beach cleanups (New Jersey State 1987). A National Park Service official in Long Island indicates that the amount of money allocated for cleaning beaches and water quality testing has tripled, however, given the need for increased monitoring and surveillance since the beach wash-up problem arose in 1988 (J. Tanacredi, National Park Service, pers. commun. 14 February 1989). Figures are not readily available on these exact costs or how prevalent such increases are.

The actual washups may not have contained much medical waste, but the perception created by media reports that these wastes were appearing with frequency on beaches might have been a deterrent to beachgoers (R. L. Associates and U.S. Travel Data Center 1988; DiLernia and Malchoff 1989). It is not clear, even with a summer of fewer washups and the attendant lack of publicity, how quickly these economies will recover. Ofiara and Brown's (1989) review of previous studies indicates that there can be economic impacts (in some cases depressing fish prices for several years) from health advisories and subsequent media reporting of them.

BEACH WASHUPS: LOCATIONS AND SOURCES

In general, beaches closest to the sources of floatable marine debris (including medical waste floatable debris) are most likely to experience floatable strandings (New Jersey State 1987; NYSDEC 1988; Swanson 1988; Swanson and Zimmer 1989). Examination of potential sources and consideration of weather factors (i.e., winds and surface currents) seem to confirm this general relationship (NYSDEC 1988; Swanson 1988; Swanson and Zimmer 1989). There are a number of likely sources of the medical wastes and other materials in the beach washups along the NYC, Long Island, New Jersey, and other nearby shores. Table 3 lists the locations and dates of beach closings in the summer of 1988.

The weather appears to be an important factor in explaining the number of large beach washups in 1988. In 1988, as in 1976 (the last time long stretches of Long Island and other Greater NYC beaches closed due to pollution), a weather pattern of winds predominantly from one direction prevailed before the major washups (Swanson 1988; Spaulding et al. 1989; Swanson and Zimmer 1989). The most significant source of floatables is the Hudson/Raritan Estuary, and wind is the primary source of movement of floatables once they reach the bight. The prevailing south-southwesterly winds of early summer 1988 made Long Island beaches particularly susceptible to beach washups (Swanson 1988). A hindcast study for Long Island confirmed this relationship (NYSDEC 1988). The State of Rhode Island concluded that the New York Bight was also the probable source of the medical waste debris on its shores in 1988 (NYSDEC 1988; Spaulding et al. 1989).

Investigation showed that the primary sources of medical waste and other floatable marine debris along the shores of NYC, Long Island, and other nearby coastlines are the Fresh Kills landfill (including barges transporting waste to it), marine transfer stations, combined sewer

Table 3.--Summary of beach closings, 1988. (Source: New York State Department of Environmental Conservation 1988.)

County	Beach	Dates
	Long Island	
Nassau	Nassau	7/6-7
	Long	7/6 (7/29 high bacteria)
	Jones	7/6, 7/8
	Lido	7/6
	Oyster Bay Town	7/7-8
	Gilgo	7/8
Suffolk	Robert Moses State Park	7/6-8
	Fire Island	7/7-8
	Babylon Town	7/8-10
	Smith Point State Park	7/10
	Quogue	7/23-27 (high bacteria)
	Shirley	7/29 (high bacteria)
	New York City	
Queens	Rockaway	7/8, 7/26-28
	Jacob Riis Park	7/17-20
	Atlantic	7/17 (7/29 high bacteria)
Kings	Coney Island	7/12-13 (7/17 high bacteria)
	Brighton	7/12-13
	Manhattan	7/12-13
Richmond (Staten Island)	South	7/11 to close of season (9/3)
	Midland	7/10-8/18
	Great Kills	7/13-28 (8/9 high bacteria)
	Miller Field	7/13-25 (8/9 high bacteria)

overflows, raw sewage discharges, and storm-water outlets. Other sources such as illegal dumping probably contribute a smaller portion of floatables.

The NYSDEC's investigation into the sources of beach washups in 1988 concluded that medical-related wastes are sent to the Fresh Kills landfill, where some debris escapes into the water from a "hospital waste mooring" (NYSDEC 1988). Eight of nine municipal marine transfer stations (MTS's) and one private MTS currently operate in NYC. The NYC Department of Sanitation is responsible for off-loading wastes from trucks to barges for transfer to the landfills. Apparently, current loading practices cause spillage at the MTS's and there is not an effective system to remove such spillage (NYSDEC 1988).

The NYSDEC also reported that sewage treatment failures occurred prior to the beach washups in 1988, followed by rainstorms which flushed out floatable material collected in storm drains during a relatively dry period (NYSDEC 1988).

Although debris from the Fresh Kills landfill, sewage discharges (including combined sewage overflows), and MTS's are the most significant sources of floatables in the Greater NYC area, NYSDEC noted that "it is clear that medical-related waste has been disposed of illegally into the garbage and into the sewers [and that] these two sources contributed to the beach debris" (NYSDEC 1988). To date, illegal disposal of medical wastes appears to be a more significant problem on land than in the waterways, but it is possible that some illegal disposal directly into the water also occurs (NYSDEC 1988).

This information on the sources of medical waste in washups has important implications for whether some types of laws and programs being proposed and adopted to address the beach wash-up problem, such as a manifest tracking system, will be adequate. Another legitimate concern is that as regulation of medical wastes increases, disincentives for illegal disposal also need to be pursued, e.g., a manifest system or vigorous enforcement.

GOVERNMENTAL RESPONSES AND RELEVANT POLICY ISSUES

Whatever their actual aesthetic, social, and economic impacts may be, a critical issue is what governmental efforts if any will be effective in addressing the problem of beach washups of medical wastes. As noted above, currently no comprehensive Federal requirements exist for the management of medical wastes (U.S. Congress 1988). The MWTA of 1988 passed by Congress was in part an attempt to address the problems of beach washups of medical wastes and illegal disposal of medical wastes.

It is not clear, however, in light of the sources which appeared primarily responsible for the beach washups of 1988, that the "cradle-to-grave" type of manifest tracking system established by MWTA will have a significant impact on the washups of medical wastes. Other actions, such as improved waste management handling at marine transfer stations and at landfills in marine areas may more directly address the problem. Increased enforcement efforts appear prudent in any case, given the need to ensure that incentives for illegal disposal do not increase if the handling, transportation, treatment, and disposal of medical waste are increasingly regulated.

The MWTA establishes a demonstration tracking system (MWTA, Sections 11001-11003) and directs the EPA and another Federal agency to undertake studies of certain medical waste management issues (Sections 11008 and 11009). The intent is to develop a basis for determining whether and in what ways the Federal Government should regulate medical wastes. The MWTA specifically applies to Connecticut, New Jersey, New York, and the Great Lakes States (Section 11001). Any of the Great Lakes States may opt out of the demonstration program and any state can opt in; Connecticut, New Jersey, and New York can petition out if they have a program at least as stringent as that of the Federal Government. Civil penalties of up to $25,000 per day for each violation, criminal penalties of up to $50,000 per day per violation, and in addition, jail terms of up to 5 years may be imposed in states implementing the tracking system (Section 11005).

On 24 March 1989, EPA established the 2-year pilot Federal tracking program authorized by MWTA by publishing its "Standards for the Tracking and Management of Medical Waste; Interim Final Rule and Request for Comments" in the Federal Register (p. 12326-12395; 40 CFR Parts 22 and 259). Yet, as EPA points out in its press release of 13 March 1989:

> "Many of the suspected sources of last summer's beach wash-up problems will not be affected by the new tracking system. Preliminary analyses of last summer's beach washups and additional EPA studies underway indicate that likely sources of the washups included improper handling of ordinary trash and sewer overflows which contain wastes from home health care and illegal drug use. To the extent that all of these sources contribute to environmental degradation, the problems will persist despite the new regulations (EPA 1989a)."

The manifest will not track medical-related wastes emanating from a number of the primary sources identified by the NYSDEC investigation. Interestingly, the cost of compliance with the requirements of the MWTA, including the manifest system, is estimated by the EPA to increase the cost of medical wastes disposal by approximately $0.08/lb on average (EPA 1989b). According to EPA (1989b), average annual compliance costs per facility range from about $3,750 for hospitals to about $70 for dentists. These figures and the per pound figure are considered to be low estimates by some waste industry officials.

In any case, New York State and New Jersey cooperatively adopted a tracking system in August 1988. It is not clear, however, whether either state will petition to opt out of the Federal program. A number of other governmental actions, including an interagency Floatables Action Plan for the New York Bight and action programs by individual states (e.g., New York State), have been initiated to address the problem of floatable medical wastes and other floatable debris in the Greater New York Harbor area (Molinari 1989; Weisbrod 1989).

The New York Bight Floatables Action Plan, a multiagency effort led by EPA Region II, is part of the New York Bight Restoration Plan. It includes such actions as studies of floatables in 1987 and 1988 and continued surveillance, regular cleanups at "key locations," other cleanup as necessary, and a communication network (Molinari 1989). In addition to expanding its public information program, NYSDEC's response to control beach washups of floatables includes combined sewer overflow abatement, improved operation and maintenance at sewer treatment plants (STP's), stricter controls at MTS's for the handling of solid waste, more stringent regulation of medical waste, and enhanced enforcement of medical and all solid waste regulations (Weisbrod 1989).

The NYSDEC anticipates that when new state medical waste regulations become effective, a capacity shortfall for medical waste disposal may result (Markell 1989). Older facilities may close if they anticipate that it will be too expensive to meet new regulations and, given the difficulties of siting new waste facilities of any type, incentives for illegal dumping could indirectly be fostered. For this reason, the state increased the criminal and civil penalties for medical waste violations in 1988 and plans an aggressive enforcement program (Markell 1989). Brooklyn District Attorney Elizabeth Holtzman supports strong enforcement efforts in the NYC area and actively prosecutes violators of existing medical waste management laws (Holtzman 1987, 1988).

Congress amended the Ocean Dumping Act (formally known as the Marine Protection, Research, and Sanctuaries Act of 1972, 33 U.S.C. Sections 1401 et seq.) in 1988 to increase the penalties for illegal disposal of medical wastes by public vessels. Some medical waste discovered along the coast of North Carolina and a few other locations was traced to discharges from U.S. Navy vessels (Associated Press 1988). According to the new amendments, civil penalties of not more than $125,000 for each violation can be assessed by EPA for "engaging in activity involving the dumping of medical waste" as regulated by the law. Criminal penalties of not more than $250,000, or imprisonment of not more than 5 years, or both, and possible forfeitures of property can also be imposed.

CONCLUSION

The beach washups of the summer of 1988 had a range of impacts (aesthetic, social, and economic) which may not have been precisely calculated, but did generate governmental responses to the appearance of medical waste on our beaches. Medical waste along our coasts also drew attention to a broader range of issues associated with medical waste management. Some of the specific programs initiated by state and local governments to address the beach washups of floatables may be most effective in the near term. The importance of the Federal demonstration tracking program for medical wastes in abating medical waste floatables in beach washups is not clear. Its significance to the improved management of all medical waste will need to be evaluated in the light of future regulatory programs. Nonetheless, using experience gained in regulating the hazardous and solid waste streams, there is opportunity for government at all levels to proceed in devising programs to manage medical waste wisely and efficiently in order to alleviate public concern, protect human health, and provide environmental protection.

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